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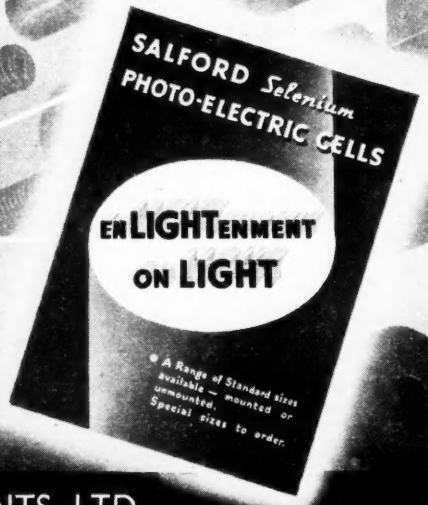
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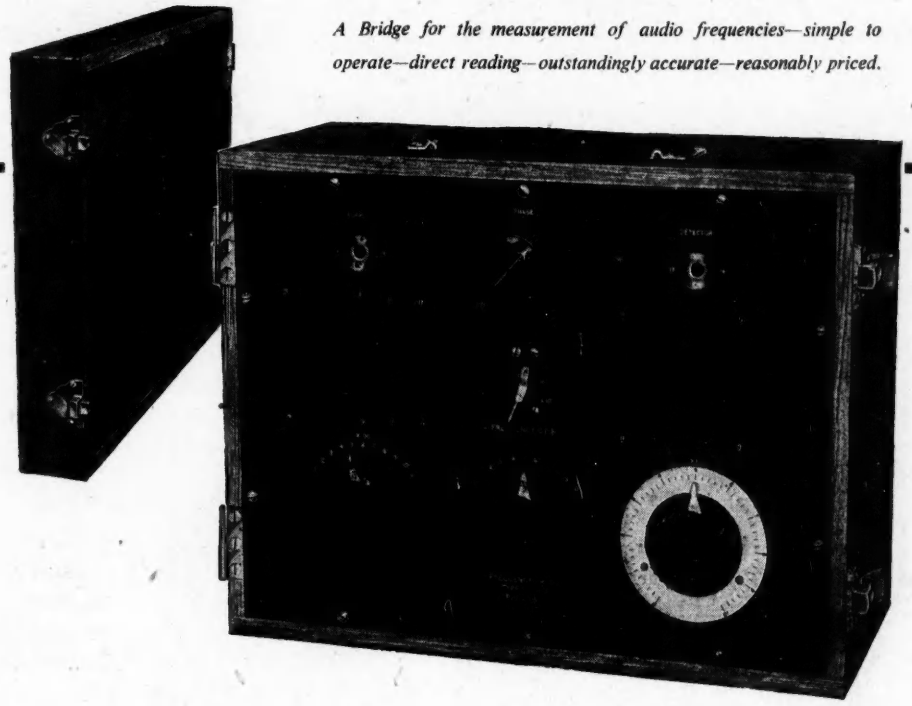

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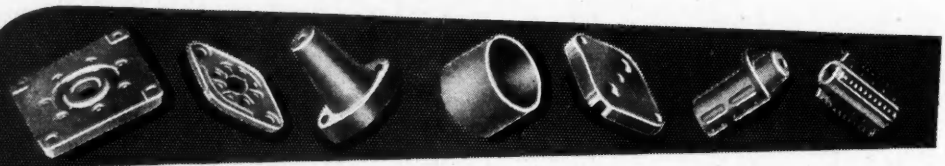

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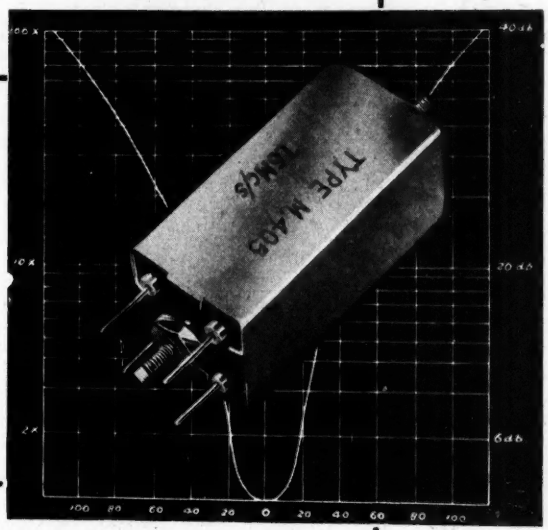

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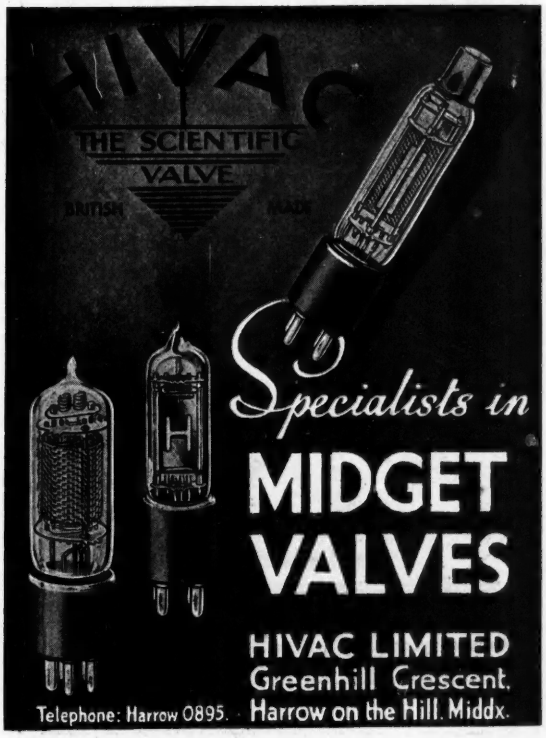

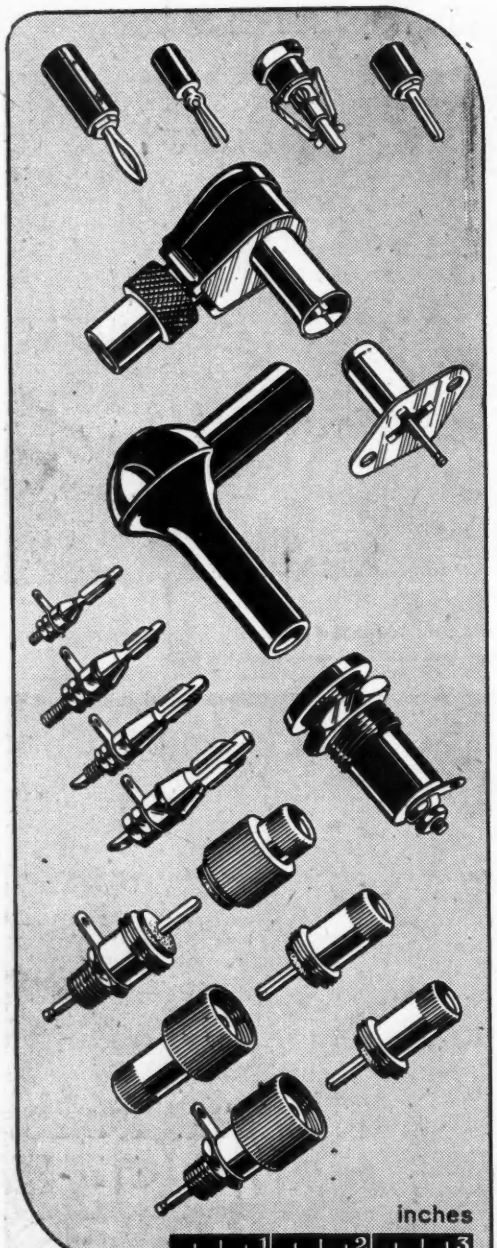

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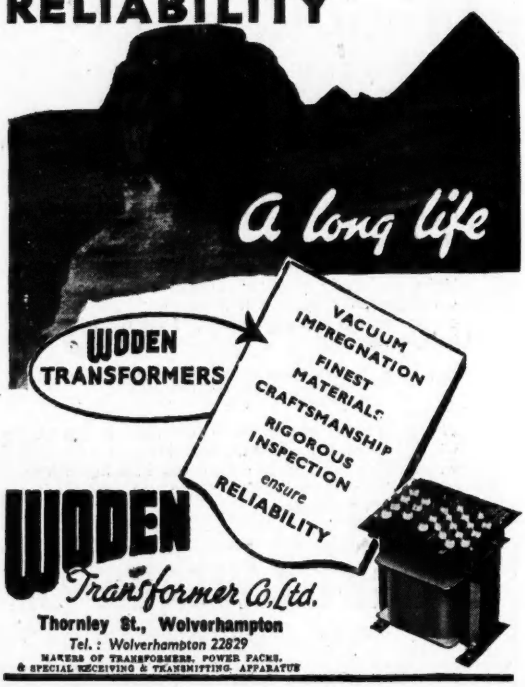

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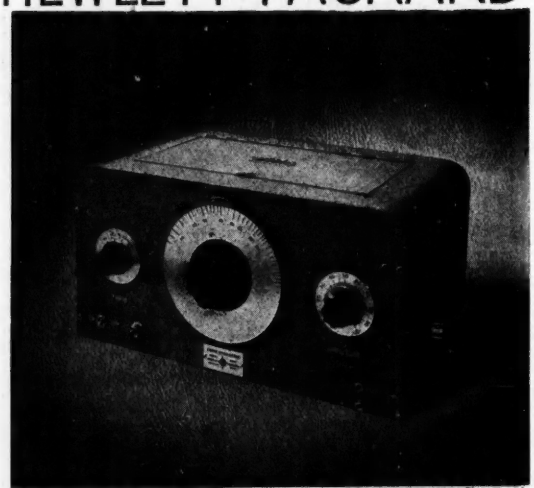

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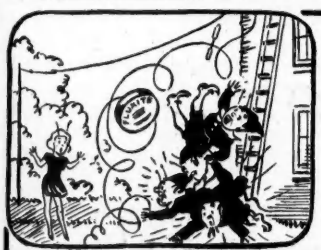

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Electronic Engineering

MARCH, 1944

Volume XVI. **No. 193.**

CONTENTS

	PAGE
Editorial—Television	403
A Modern High Tension Laboratory ...	404
X-Rays in Electrical Engineering	405
Pulse Generation	408
A Note on Mr. Nethercot's Paper on "Recording of High Speed Transients"	411
Tracking in Superhet Receivers—Part I ...	412
The Electron Microscope	414
March Meetings	423
A New Discovery in Physics ??	424
High Frequency Therapy—Part 7	426
Correction to "Laminated Wood as an Insulator"	431
Correspondence	432
Notes from the Industry	433
Book Reviews	434
Abstracts of Electronic Literature... ...	436
Electronic Stabiliser for Calibrating Voltage	438

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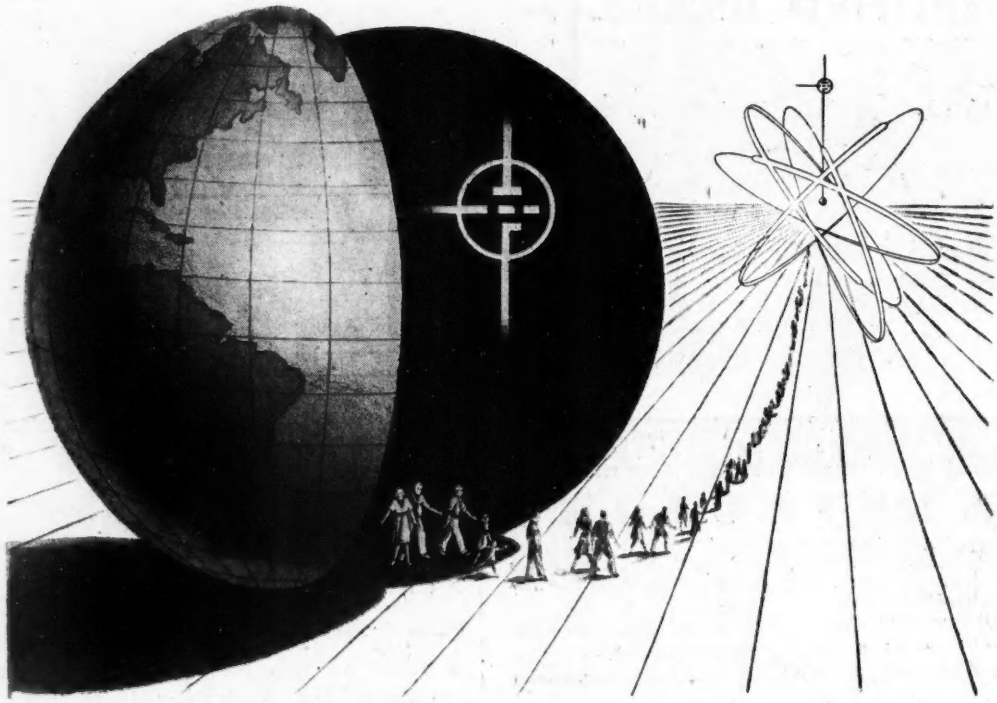

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Television

THE future of television after the war has been the subject of discussion among radio engineers for some time.

The ball was set rolling by the informal discussion opened by Mr. B. J. EDWARDS at the I.E.E. Wireless Section in May last,[1] and this was followed by the paper by K. I. JONES and D. A. BELL, in which television was fitted into a general scheme of post-war broadcasting.[2]

On February 16, the British I.R.E. held a general discussion on the same subject, opened by Mr. L. H. BEDFORD, and his main headings summarise the points which have been considered by all the various speakers. He visualises three possibilities:

(a) The immediate resumption of the television service with an extension to the provinces as rapidly as possible.

(b) The earliest possible resumption of the service with improved standards consistent with the economic and technical limitations of the times.

(c) Indefinite deferment of the re-opening of the service until fundamental improvements can be carried out, such as considerable increase in definition, colour, and possibly stereoscopy.

Mr. BEDFORD is also of the opinion that the use of frequency modulation for the sound programme would greatly improve the quality of the service.

Last week Mr. B. J. EDWARDS again reviewed the position in a paper before the I.E.E. Wireless Section[3] and gave a very fair presentation of the pros and cons for resumption of the service on the existing standards.

The carrier frequency and video band-width gave minimum echo-reflexion trouble and a satisfactory signal-noise ratio. Linking with the provinces would be possible by concentric cable, whereas no cable is at present available to handle a band-width much in excess of that formerly used.

Just prior to the war, manufacturers were in a position to produce quantities of receivers at a reasonable cost and if these facilities have not been scrapped, they should be able to produce the equipment within a few months of the cessation of hostilities.

Against these points it is agreed that the television standards before the war were far from perfect, and were even inferior to the American standards. The prestige value of a greatly improved system would have a marked effect on our export trade and the colonies would have every encouragement to follow our example.

Mr. EDWARDS views the resumption of television on the old standards "with the greatest apprehension," since it would involve the country with the old system for many years, and give the public an indifferent service which would react unfavourably on the whole future of television.

There is one section of the community that has not so far voiced its views on the future of television, and that is the pre-war regular viewers, As Mr. EDWARDS says, they number only about 20,000, but they have the advantage of being able to speak from experience.

Possibly a form of Gallup poll would yield some interesting and unexpected information on the preference of those whose receivers are gathering dust. It would not be surprising, for example, to find that reliability and entertainment value ranked of equal importance with improvement in definition.

ELECTRONIC ENGINEERING MONOGRAPHS

The second booklet in the series of Electronic Engineering Monographs is now available. The title is:

PLASTICS IN THE RADIO INDUSTRY

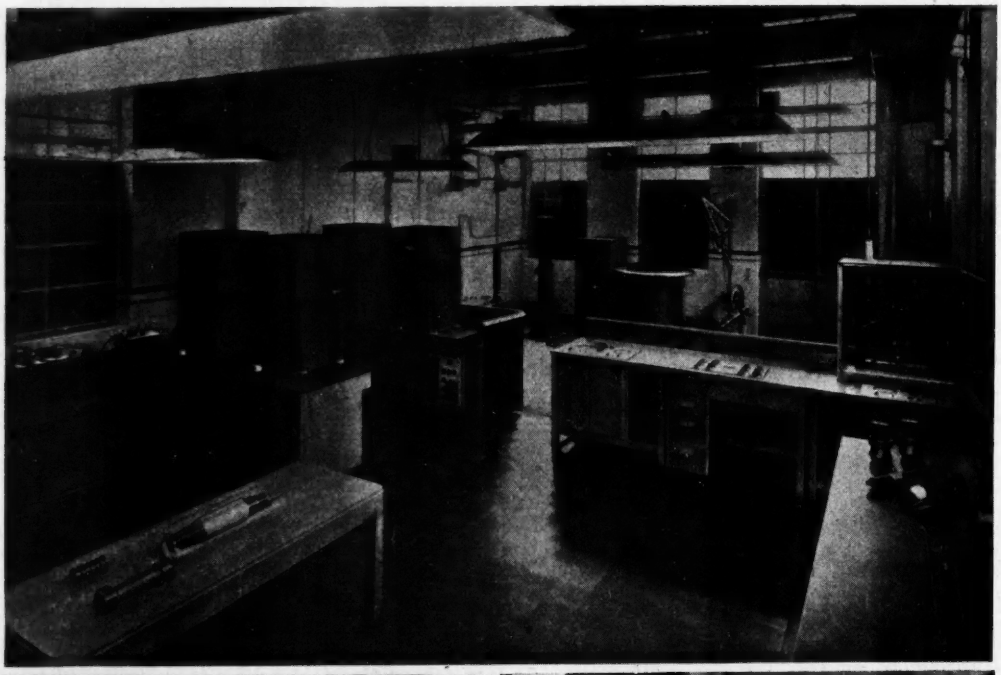
by E. G. Couzens, B.Sc., A.R.C.S. and W. G. Wearmouth Ph.D., F.Inst.P.

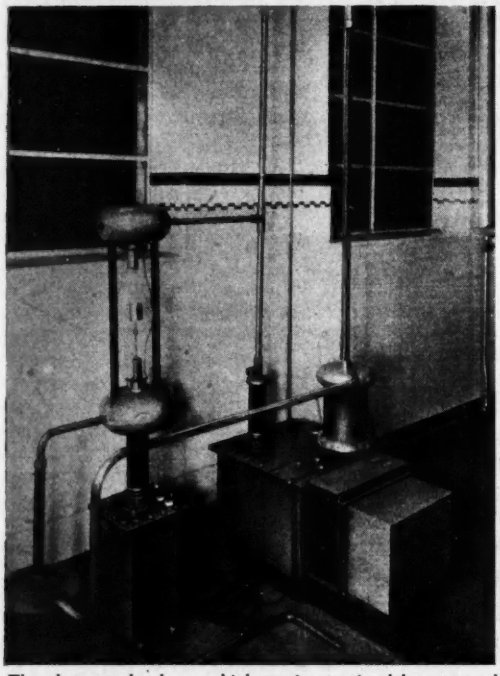
and the subject matter is based on a series of articles which have appeared in this journal, completely revised and expanded to include information on the manipulation of Plastic Materials

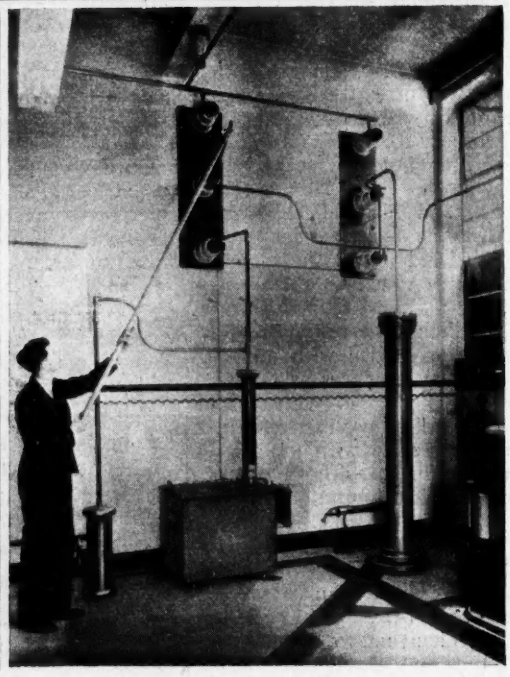
The Monographs are obtainable through technical booksellers or direct from the Publishers at 43 Shoe Lane, E.C.4, price 2/6 or 2/8 post free.

[1] *Electronic Engineering* July 1943, p. 60 [2] *ibid.* Jan. 1944, p. 320 [3] To be published.

A MODERN HIGH TENSION LABORATORY







The photographs show a high tension testing laboratory which was recently designed and installed by the Metropolitan-Vickers Co., for Messrs. Turner's Asbestos Cement Co., Manchester. The top photograph is a general view of the laboratory, and below (left) is a 50 kV d.c. testing set with 35 kV. transformer. On the right is a 105 kV. transformer fitted with crest voltmeter, compressed air condenser and oil tank control.

(By courtesy of Messrs. Turners Asbestos Cement Co.).

X-Rays in Electrical Engineering

By L. MULLINS, M.Sc., Ph.D., A.Inst.P.*

THE generation of X-rays is essentially an electronic phenomenon, and ever since their discovery by Röntgen in 1895, electrical engineers have been constantly improving X-ray generating equipment. The outstanding stages in the development of modern X-ray apparatus were undoubtedly the introduction, in 1912, of the Coolidge tube incorporating a heated filament as an electron source, thus allowing independent control of X-ray quality and quantity; the development about 1926 of the self-protected X-ray tube, so designed that apart from the outlet port, the tube was ray-proof; and the use of high-tension cables to render the X-ray tube and its subsidiary gear shockproof. More recently, three other developments, of interest alike to electronic engineers and users of X-ray equipment, have been published. The first was reported by Oosterkamp[1] who, in order to obtain an extremely intense X-ray beam of very short duration, utilised a condenser discharge circuit (a circuit previously applied in X-ray work) so arranged that the filament current was momentarily boosted during the condenser discharge. Soon after, Slack and Ehrke[2] again striving for an intense X-ray output of short duration, applied the condenser discharge technique to a specially designed cold cathode X-ray tube. In this, the condenser discharge induced an exciting discharge between the true cathode and a subsidiary electrode which started the main discharge, the exciting current then being quenched immediately by a high resistance in the subsidiary electrode circuit. By this means Slack and Ehrke obtained X-ray photographs in one-millionth of a second, of bullets passing through wood and of the flow of dust in the inlet duct of an electric vacuum cleaner. About the same time news came from America of the successful development and application of an industrial X-ray equipment working at 1,000 kV., capable of penetrating up to eight inches of steel.[3,4] In this the chief features of interest to the electronic engineer are the resonance transformer surrounding the Coolidge type self-rectified X-ray tube and the use of the gas "Freon-12" (dichlorodifluoro-methane) under pressure as the insulator.

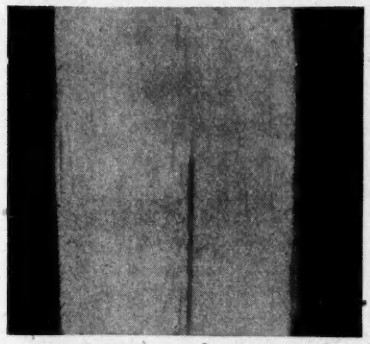


Fig. 1. Radiograph of part of a transformer winding on its cardboard former. Note the wandering of the windings towards the edge of the cardboard former and the lack of uniformity in the winding at the centre.

Despite these noteworthy contributions of electrical engineering to the design of X-ray equipment, the applications of X-rays in the electrical industry have been by no means extensive. In fact, up to about ten years ago, these applications were mainly limited to the inspection of cored arc and furnace carbons, of silver impregnated carbon contacts, of metal shrouded heater elements and of wireless valves.

Now, however, X-rays are being increasingly employed in the electrical industry, not only for the routine inspection of raw and finished products, but also for investigating the fundamentals of fabrication and the behaviour of hidden components under working conditions. The technique used depends on the nature of the problem. Where gross defects, such as faults in assemblies or in plastic mouldings, are being sought, the specimen is placed in the X-ray beam, and the intensity distribution of the transmitted beam is either viewed on a fluorescent screen or recorded on a photographic film placed adjacent to the specimen; this technique is termed "radiography"[5], although screen examinations should be strictly classified under "fluoroscopy." When the information sought concerns the spatial distribution of the atoms, the technique then applied is that of X-ray crystal analysis,[6] involving the diffraction of X-rays by the atomic planes according to the Bragg law as described below.

Applications of Radiography

Probably the most widespread application of radiography in electronics is in the inspection of thermionic valves, the method being applicable to both glass and metal shrouded valves. According to Gibson and Rabuteau[7] such inspection reveals inaccurate centreing or alignment of electrodes, distortion of electrodes occurring during exhaustion, thin spots in anodes, burnt-out or distorted filaments and grids, and loose filament connectors. Rooksby and Jackman[8] have indicated that, in addition, the radiography of valves whilst working will reveal filament distortion due to heating.

Similarly, radiography has been successfully applied to the inspection of all types of assemblies, such as electric cooker elements, telephone equaliser units and sparking plugs.[9] A typical example of this type is illustrated by Fig. 1, which shows part of a transformer winding on its cardboard former. The technique was used to detect any wandering of the winding towards the edge of the former where it may cause a short-circuit when mounted on its iron core. This radiograph shows some wandering of the wire at each edge and some lack of uniformity at the centre of the winding. This same technique has been used to examine the extent of the flow of solder in joints, since inefficient soldering may be a potential source of poor electrical continuity. The outward appearance of a good and bad joint may be identical, but the X-ray image (*see* Fig. 2) will readily distinguish good and bad workmanship. Moreover, the knowledge that their work may be so examined has a salutary effect on the operators, with a consequent raising in the standard of workmanship. In the same way radiography may be used to investigate the internal features of spot welds[10] such as those used in valve electrode assembly.

The importance of maintaining concentricity of the core in heavy electric cable is well appreciated by all electrical engineers, to whom the danger of flaws in the insulation are equally evident. Satisfactory non-destructive inspection of the finished product can only be achieved by radiography;

* Research Laboratories, Messrs. Kodak, Ltd.

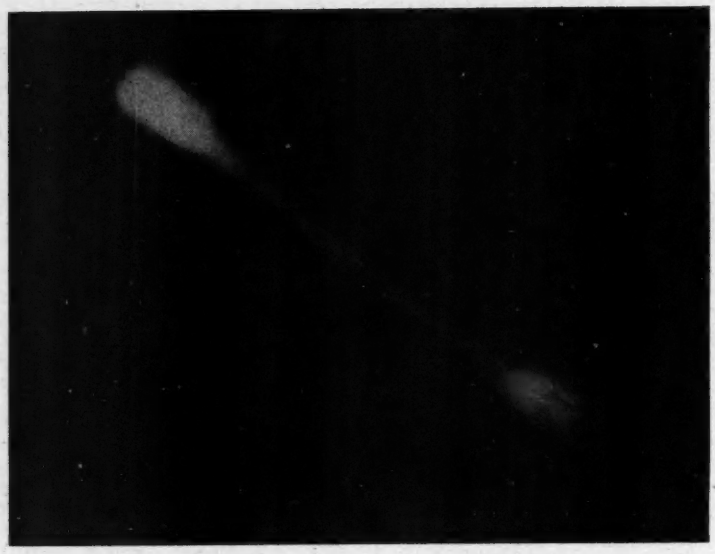


Fig. 2. Radiograph of good (left) and bad (right) soldered joints.

accordingly, Davis, Crowdes, Merkel and Hicks[11] have produced special equipment for this work. Since the fluoroscopic examination is cheaper than the more permanent film records, this apparatus is designed to permit fluoroscopic screening of the cable whilst it is passing through the apparatus. Two X-ray tubes, arranged with their beams at right angles, and a system of mirrors permit examination in two planes simultaneously. When the operator observes a faulty section, a film record may be made at will, the suspected portion of the cable being marked automatically. The importance of the defects in the suspected region is then finally decided by reference to the radiograph in which the sensitivity of fault detection is some five to seven times greater than in the screen image. The X-ray image of frayed leads, hidden by the insulation, in light flexible cable is shown in Fig. 3.

Where radiographic examinations cannot be made by X-rays, owing to insufficiently high penetration of the X-rays or to the limitations imposed by the size or the restricted mobility of the X-ray set, gamma-rays may sometimes be used to advantage. These rays, emitted by radio-active substances, correspond roughly in quality to X-rays generated at voltages from 1,000 to 2,000 kV. The gamma-ray source usually consists of a small platinum capsule, containing about 250 milligrams of radium element: its small size makes it ideal for radiography in inaccessible places and for radiography in the field. Rooksby and Jackman[8] for instance, have used a gamma-ray source for radiographic inspection of large transmitting valves at the operating station. A further important application of both X-rays and gamma-rays of interest to the electrical engineer, is their use in the radiographic inspection of copper castings[12] intended for switchgear. The effective use of this technique not only helps to eliminate defective castings, but also indicates improvements in foundry technique, which will lead to even more reliable castings.

Applications of X-ray Crystal Analysis

X-ray crystal analysis is still regarded by some as nothing more than an academic research method. Its industrial applications, however, are steadily increasing, and already many firms have appreciated its value both as an investigatory technique and an inspection tool. For instance, X-ray crystallography has been applied as a routine method for determining the crystal orientation of sapphire crystals for meter bearings[13] and of rough pieces of quartz intended for oscillator and resonator plates[14]. The importance of the latter application need not be stressed to those familiar with the fundamental dependence of the piezo-electric properties upon the crystallographic orientation of the quartz plate.

Solid substances, such as metals and insulating media, generally show no visible external crystallographic symmetry. Nevertheless, they are crystalline in that the grains of which they are made up, have an orderly internal arrangement of atoms, which controls their physical properties, such as cleavage. For most of the common industrial metals the basic crystal form is body-centred cubic, face-centred cubic, or hexagonal. In such regular arrangements of atoms throughout space, the atoms lie in planes, each being one of a set of planes with a constant distance of separation. These sets of planes vary, not only in their distance apart, but also in atomic density, and in their relation to a fixed set of axes.

The spacing of the planes in a crystal is of the same order as the wavelengths of X-rays, and accordingly, a parallel set of these planes will behave towards X-rays in a manner similar to that of diffraction gratings with visible light. Suppose a monochromatic beam of X-rays of wavelength λ is incident on a set of planes of spacing d and making an angle of θ with these planes, then refraction will occur, provided first of all, that the two laws of reflexion are obeyed. Secondly, since X-rays can penetrate the specimen, the beam is partially reflected by a large number of parallel and equidistant planes: consequently, reflected waves will arise with a constant phase difference between them, and these will reinforce if these phase differences represent a whole number of wavelengths. With this condition satisfied, a reflexion will occur; otherwise, the subsidiary reflexions will interfere and the nett intensity will be zero. The necessary condition for reinforcement is readily deduced from Fig. 4, in which it is seen that the path difference should equal $n\lambda$ where n is a whole number. It follows then that the required condition, known as the Bragg equation, is $n\lambda = 2d\sin\theta$. It is thus seen, that provided the wavelength of the radiation used is known

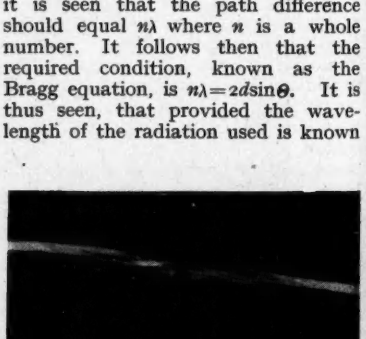


Fig. 3. Radiograph showing frayed leads in insulated electric cables.

and θ can be deduced from the set-up of the crystal and the recorded pattern, then the separation of the planes giving rise to the reflexion will be obtainable. This in turn can be related to the separation of the atoms in the crystals.

The technique, being dependent on the diffractions from atomic planes, may be applied with high hope of success to all problems fundamentally dependent on the basic crystal structure, and in fact, the method may be used for the identification of substances according to their crystal pattern, so that the method supplements analysis by chemical means[15]. Moreover, the technique is extremely valuable in investigations on mixed crystals, which constitute an intimate combination of two or more substances (generally having a similar crystal form) in which one of them has entered the crystal lattice of the other. In these circumstances the dimensions of the resulting unit lattice differ from those of the simple single substance, the difference being related to the amount of the second substance present. Hence the amount of the second component may be deduced from the crystal pattern once the mixed crystal system has been investigated. This property proved valuable in an investigation of the thermionically active coating used for the cathodes of wireless valves.[16] The coating consists of barium and strontium carbonates which, when sealed in the valve, are heat-treated to convert them into the oxides. The efficiency of the coating is dependent upon the barium to strontium ratio and on the crystalline form of the oxide, factors which may be readily checked by X-ray crystallography. Again by using X-ray crystal analysis and an ingenious method for collecting the oxide (which is unstable in the air) formed under various conditions, Benjamin and Rooksby[16] were able to show that the most efficient coating is one containing roughly equal proportions of the two oxides and in which the oxides are present as mixed crystals. They also found that a fall in thermionic emission due to operating the valve at too high a temperature for long periods could be related to a fall in the barium content, presumably by volatilisation.

In addition, X-ray crystallographic

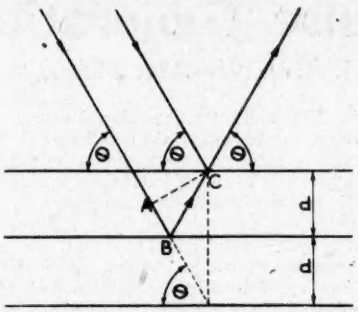


Fig. 4. Diagram illustrating the derivation of the Bragg equation. AC represents the wave-front of the two incident rays; the path difference between the two rays at C is given by (AB + BC).

Reinforcement occurs when this path difference is a whole number of wavelengths, i.e. when $n\lambda = 2d\sin\theta$ where "n" is a small whole number and "d" is the separation of the atomic planes giving rise to the diffracted rays

investigations have provided valuable information on the breakdown of high tension electric cables[17], on the structure of micas[18], rubbers[19] and synthetic resins[20 21 22], on luminescent materials, such as those used in cathode-ray tubes and in certain gaseous discharge tubes[23] on carbons for arc lamp electrodes[24 25], and on the reactions inside the lead-acid accumulator[26]. Those properties of metals fundamental to their application in electrical engineering have also received attention from X-ray crystallographers, and a wealth of information is available on investigations on such items as electric furnace resistor ribbons[27], filament and heater wires[28], magnet and transformer steels[29 30 31 32], insulating materials[33], nickel-iron alloy powders for loading and radio cores[34], and the directional properties of rolled metal sheet such as is used in the production of electrode assemblies in thermionic tubes[35 36].

It is thus seen that the contribution of X-rays to the advancement of the electrical industry is far-reaching, and it can be safely said that the full value of the discoveries to date has yet to be realised. This realisation is dependent on the electrical engineer obtaining a sound knowledge of the scope and possibilities of the X-ray techniques, and it is hoped therefore, that the list of references given in col. iii will serve to stimulate further studies both in the fundamentals and the applications of the many aspects involved.

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Pulse Generation

By J. M. A. LENIHAN, M.Sc., A.Inst.P.*

PULSES are widely used in several branches of electronics—among which may be mentioned the control of thyratron circuits for operations such as welding, and the synchronisation of transmitter and receiver time bases in television—as well as for the investigation of various problems of radio-wave propagation. These applications depend on quite simple principles, and the literature concerning them is adequate. The methods used for the generation of pulses do not appear to be so well known; references to them are thinly distributed over a number of journals and it may be worth while here to summarise the technique involved.

The arrangements used may be divided, though not very sharply, into two classes: (A) circuits which generate pulses directly; (B) circuits delivering an output which may be converted into pulses by the use of suitable shortening circuits.

A, 1. Thyratron circuits

If a condenser is charged through a resistance the potential difference across it rises exponentially. A thyratron connected across the condenser and suitably biased conducts when the p.d. has reached a predetermined value. The condenser then discharges and current flows through the valve. A voltage pulse may be obtained from a resistance connected in the path of this current (R in Fig. 1). To obtain a pulse of short duration, CR must be small, though if R is too small an excessive current may be drawn from the valve, causing damage to the cathode. If the condenser is charged from a source of alternating current, the recurrence frequency of the pulses is the frequency of the supply, and the amplitude may be adjusted by varying the grid bias voltage. A refinement of this method is shown in Fig. 2, in which C charges through a diode valve connected to the secondary of a mains transformer. A separate winding is used for synchronising.[1]

A, 2. The squegging oscillator

An oscillator functions satisfactorily only if grid-leak bias is used. In this system (Fig. 3a) the condenser C charges at the peak of each positive half cycle, when grid current is drawn, and discharges through the resistance R until the next peak occurs. If C and R are correctly chosen, the discharge is slow enough to maintain a fairly constant bias. If for any reason the amplitude of the oscillations increases slightly, more grid current is drawn, and the electrons captured by the grid produce an increased negative bias in returning through R to the cathode. The anode current thus decreases and the amplitude is decreased. Similarly, if the amplitude falls below its normal value, less grid current is available to charge C and the grid bias is smaller, so that the anode current increases. If the coupling between anode and grid circuits is larger than the value necessary to maintain oscillation, the amplitude builds up to a considerable value soon after the commencement and a large grid current is drawn, leading to a large negative bias. If the time constant CR is large compared with the period of the oscillations, the bias increases more rapidly than the condenser can discharge through R, and eventually reaches the cut-off value, when anode current ceases. The charge on C then leaks away through R and when the bias is sufficiently reduced oscillation recom-

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Fig. 1. Basic thyratron circuit.

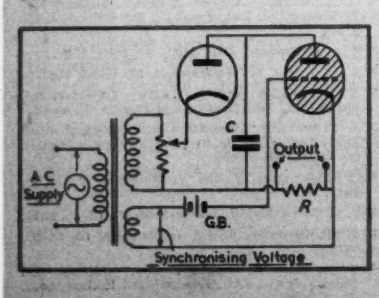

Fig. 2. Improved thyratron circuit operated from A.C. mains.

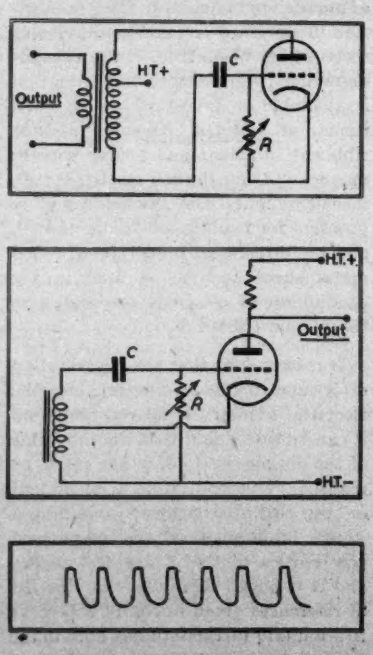

Fig. 4. Forms of blocking oscillator circuit and the pulse shape produced.

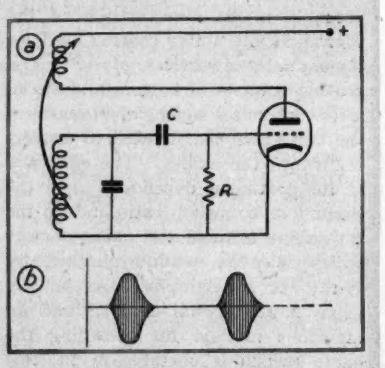

Fig. 3. The "squegging oscillator" circuit.

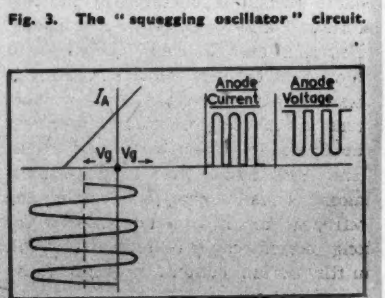

Fig. 5. Form of shortening circuit.

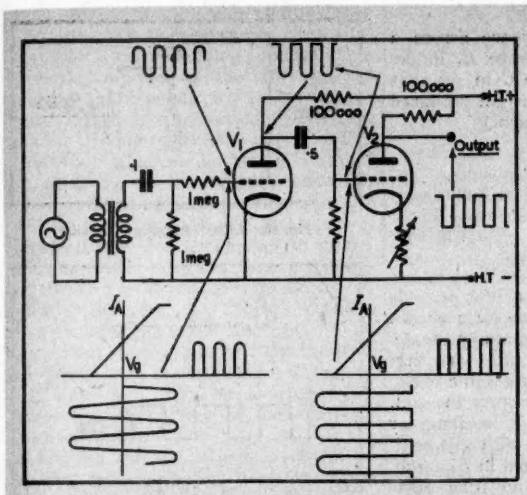

Fig. 6. Production of square wave pulses from shortening circuit with amplifier

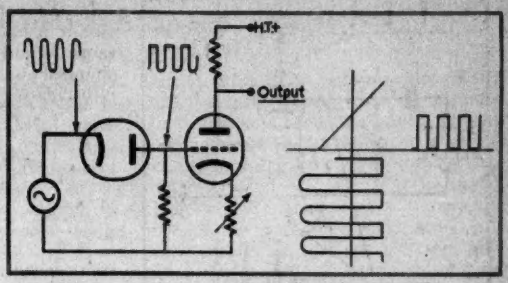

Fig. 7. Another method using half-wave rectifier.

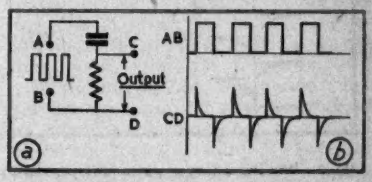

Fig. 8. Condenser-resistance circuit for producing sharp pulses.

mences. This interrupted oscillation is known as *squegging*, and the conditions necessary to produce it are (a) close coupling between anode and grid circuits; (b) a grid bias network with large time constant. The squegging oscillator generates bursts of oscillations which can, however, be made narrow enough to be classed as pulses. The output may be taken from the anode or across a coil coupled to the anode circuit. A more detailed discussion of squegging oscillators and their uses will be found in references [2] [3] and [4].

A, 3. Blocking oscillators

Interrupted oscillations may be generated by the process of blocking, which is an extreme case of squegging. If in the circuit of Fig. 3a the anode and grid circuits are very tightly coupled, the grid acquires a large positive potential at the peak of each cycle and the electrons forming the grid current may be sufficiently accelerated to cause secondary emission. The effect of electrons leaving the grid in this way is to make it more positive with respect to the cathode, and the process is therefore cumulative. Increase in grid current causes the circuit to become heavily damped and oscillation ceases on this account. The positive grid potential then decays through the leak resistance until conditions are again favourable for the commencement of oscillations. In order to obtain the required close coupling between anode and grid circuits an iron-cored transformer is generally used, and the blocking oscillator is therefore suitable only for use at audio frequencies. Typical circuits are shown in Figs. 4a and 4b. This arrangement is capable of generating various waveforms; for pulse production the most suitable shape is that shown in Fig. 4c, which can usually be obtained without critical adjustment. The sharpening circuits to be described below will shorten the pulses generated by a blocking oscillator, and will also produce pulses from a voltage of rectangular waveform. The methods by which a waveform of this nature may be obtained will now be outlined.

B, 1. Squaring circuits

A voltage of approximately rectangular waveform may be produced by a sine wave generator followed by a number of suitably biased amplifiers. If a sinusoidal voltage of large amplitude is applied between the grid and cathode of a valve the effect is as shown in Fig. 5. The valve is driven beyond cut-off during the negative half-cycle and this portion of the wave is therefore made rectangular. At the positive peak, however, grid current flows through the leak resistance or other return path, setting up a negative bias which moves the operating point further to the left along the V_g axis (Fig. 5). It is therefore impossible to drive the valve to saturation at positive peaks, and the wave retains a rounded shape. The output voltage, which is in antiphase to the anode current, has the form shown in Fig. 5. If this is applied to another amplifying stage, the rounded end is made rectangular on account of grid cut-off, and the upper half cycles undergo linear amplification, retaining their shape. The final output is of the form shown in Fig. 6. In the circuit of Fig. 6 the alternating voltage is applied to V_1 from a transformer. A potential divider is formed by the resistance R (one megohm) and the grid-cathode impedance of the valve, which, on account of the considerable grid current, is fairly low. Bias for V_2 is provided by a cathode rheostat.[5]

B, 2. Rectifier circuits

Another method is to use a half-wave rectifier followed by an amplifier.[6] The operation of this arrangement will be understood by reference to Fig. 7.

Pulse Sharpening Circuits

1. The C—R circuit

If a rectangular voltage wave is applied to a circuit consisting of resistance R in series with capacitance C, the nature of the potential difference developed across R depends on the value of the time constant CR in relation to the period occupied by one cycle of the input voltage. A detailed analysis is given in reference 7. If CR is small, application of a rectangular wave gives an output consisting of alternately positive and negative pulses which are narrow near the peaks but broader at the base (Fig. 8). These pulses may be sharpened by an amplifier stage biased so that only the tips of the positive peaks are amplified[8] (Fig. 9). It may be mentioned here that the clipping action of a valve has been used to produce pulses from the output of a full wave rectifier[6] (Fig. 10).

The voltage developed by a blocking oscillator may be shaped using a C-k circuit with the result shown in Fig. 11. After clipping with the circuit of Fig. 9, it is possible to reduce the pulse-width to 10 microseconds without difficulty.

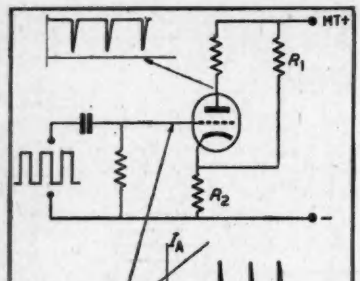

Fig. 9. The sharpness of pulse is improved by an amplifier stage.

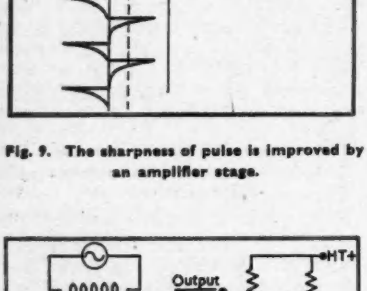

Fig. 10. Circuit for producing sharp pulses from a rectifier.

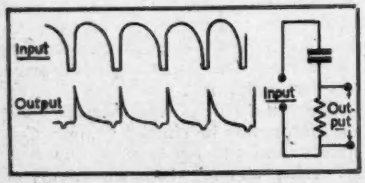

Fig. 11. Sharpening of pulses from blocking oscillator

2. The L—C—R circuit

If the potential difference across a circuit containing resistance R, inductance L and capacitance C in series is changed suddenly, the current produced is oscillatory, with frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

if $$\frac{R^2}{4L^2} < \frac{1}{LC}$$ (Fig. 12)

If R is increased, the oscillations are more heavily damped and it is possible to obtain a current of the form shown in Fig. 13a, in which the amplitude decreases almost to zero after the first half cycle.[9] A voltage of the same waveform may be taken off across the coil. The effect of applying a rectangular wave to a L-C-R circuit with this critical value of R is illustrated in Fig. 13b. One positive and one negative pulse are produced from each cycle of the input. The duration of each of these pulses is approximately one half of the period corresponding to a frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

This can be made much less than the period of the input voltage, and the circuit thus acts as a pulse-shortening device. This arrangement, known as a *ringing circuit*, may be used to shorten pulses of any shape, provided that the waveform is steep at one point in each cycle. The pulses shown in Fig. 13b may be made sharper still by the use of an amplifier biased so as to amplify only the tips of the positive peaks (Fig. 9).

Miscellaneous Circuits

The multivibrator may be used to generate an approximately rectangular voltage wave. It consists of a two-stage amplifier with the anode of each valve connected through a condenser to the grid of the other (Fig. 14a). The operation of the circuit is as follows. The initial state, with both valves conducting, is unstable. A small change in the current flowing through one of them leads to the production of relaxation oscillations. Thus, if the current through V_1 increases for any reason the following chain of events occurs:—

1. Potential difference across R_3 increases.
2. Potential of anode of V_1 decreases.
3. Potential of grid of V_2 decreases.
4. Anode current of V_2 decreases.
5. Potential of anode of V_2 increases.
6. Potential of grid of V_1 increases.
7. Anode current of V_1 increases.

The process continues rapidly in this way. The sudden decrease in anode current of V_2 constitutes a positive vol-

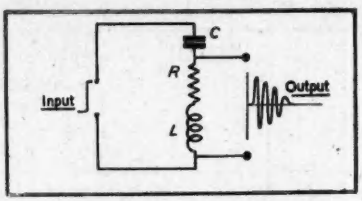

Fig. 12. LCR "Ringing" Circuit

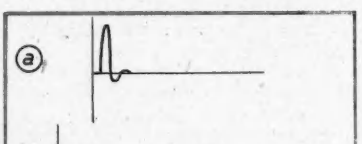

Fig. 13a. Output from LCR Circuit with R near critical value

Fig. 13b. Shaping of square wave by LCR circuit

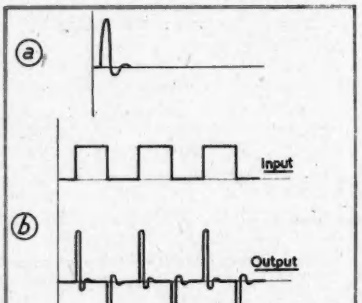

Fig. 14a. The multivibrator

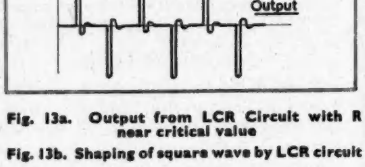

Fig. 14b. Grid-cathode voltage from asymmetrical multivibrator

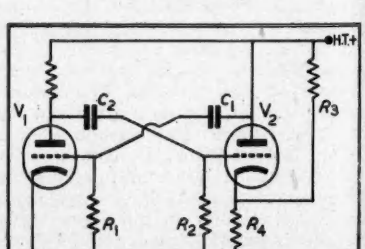

Fig. 15. Kipp Relay

tage impulse at the anode of this valve, and the grid voltage of V_1 rises suddenly by a corresponding amount. This pulse is amplified by the valve V_1 and appears at the anode as a large negative pulse which is transmitted to the grid of V_2, driving it beyond cut-off. The condenser C_2 then discharges through R_2 until V_2 conducts again, when the cycle outlined above is performed in the reverse direction. To generate a waveform suitable for conversion to pulses it is desirable that the time constants of the two grid-bias circuits should be widely different, C_1 being perhaps twenty times greater than C_2. The waveform then available from the grid of either valve is of the form shown in Fig. 14b and may be sharpened by various combinations of the methods outlined above.

Another circuit, which is useful in dealing with pulses of irregular shape or recurrence frequency, is shown in Fig. 15. It consists of a multivibrator in which one valve is permanently biased beyond cut-off by the potentiometer R_3 R_4 connected across the high-tension supply. In this state, current flows through V_1 only and the circuit does not function as a multivibrator. If a sufficiently large positive pulse is applied to the grid of V_2, the bias is lifted above the cut-off value and current begins to flow in this valve. The circuit then operates for one cycle as a multivibrator, after which it returns to its original condition until another pulse is applied to V_2. The output, taken from either of the anodes or grids, is of the usual multivibrator waveform. The frequency with which the output wave recurs is the same as the frequency of the input pulses, but the shape of the output wave depends only on the circuit elements connected to V_1 and V_2. Thus a succession of pulses of any shape applied to the grid of V_2 is changed into a set of regular pulses, which may be shaped by the various methods described above. The multivibrator used in this way is known as a *Kipp relay*.

Pulse generators involving mechanical devices have not been described here since they are of no great interest electrically. Details will be found in reference 1.

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A Note on Mr. W. Nethercot's Paper on "Recording of High Speed Transients"

by H. MOSS, Ph.D.*

Mr. Nethercot's slides are remarkable examples of ultra high-speed recording on a medium voltage sealed-off cathode-ray tube, and he has almost succeeded in invading the region normally regarded as the preserve of the continuously pumped high-voltage instrument. Although by special design the latter can be made to operate at speeds of the order of 50,000 km/sec. they are rarely required to work above about 5,000 km/sec., which is the order of speed obtained by Mr. Nethercot on a simple sealed-off tube used at only some 5 kV. It is true that the higher recording efficiency of the continuously pumped instrument gives it an inherent advantage at the most extreme speeds. The wasteful conversion of electron energy to light on a fluorescent screen is avoided. In spite of the losses thus incurred, recording by lens and camera from a fluorescent screen is possible at the highest speeds, although the process is much more wasteful in beam energy. Dodds (*Arch. f. Elektrot*, 27, p. 531, 1933) has described such recording at the enormous velocity of 42,000 km/sec., but this required a gun delivering 1 ma. at 70 kV. In practice, though, such speeds are so rarely encountered that in my view much more attention might well be given to the possibilities of the far simpler sealed-off tubes. As Mr. Nethercot has shown, it is possible to cover a good deal of average high-speed single-stroke work on standard commercial tubes, provided the anode voltage is not too restricted.

In the region of 5,000 km./sec. it is undeniable that the performance of almost any standard, present-day sealed-off tube is very marginal. Working under such conditions is very trying, and necessitates lenses of the utmost aperture, together with some form of intensifying of the developed emulsion. It would seem, therefore, that there is room for the commercial development of a sealed-off type capable of operation at some 20,000 volts with a beam current of the order of 1 ma. This should permit a considerable relaxation in the stringency of the photographic requirements.

It was pointed out during the discussion that the difficulty of screen charging on high-voltage tubes might not arise in the case of single-stroke working. In continuously pumped instruments, the screen is normally deposited on a metal plate, so that the effects of conduction are sufficient to prevent the development of gross potential differences between the screen and the final anode. In the ordinary glass envelope tube, the effects of conduction must be negligible, so that the screen maintains its potential by secondary emission. It is well known that for most fluorescent materials the secondary emission coefficient falls below unity for incident electron velocities above values corresponding to some 6-7 kV., so that the screen potential normally limits at about this figure with respect to cathode. Further increases of anode potential do not then increase the trace brilliance.

In considering the suggestion that such screen charging might not occur on single stroke working on account of the small total quantity of electricity delivered to the screen, let us suppose that the gun delivers 1 ma at 25,000 volts, that the average writing speed is 5,000 km/sec. over a trace length of 10 cms. Suppose furthermore that the screen is equivalent to an insulated conducting surface having a capacity of 1 $\mu\mu$F. Application of the formula $V = Q/C = \frac{1}{C}\int i.dt$ then shows that the rise in potential per stroke is only 20 volts. This is negligible in relation to 25,000 volts, so that in spite of the rather arbitrary assumption about the equivalence of the screen to a capacity of 1 $\mu\mu$F. it does seem certain that the screen charging would be negligible.

The general standard of photography of traces on sealed-off tubes is often lower than it need be, and this may have given rise to the impression that the continuously pumped instruments are inherently superior in respect of focus quality. Often the apparent superiority of the latter type is due to its lack of portability and heavy shielding, so that it is usually operated without any interference from stray fields. Modern sealed-off tubes are quite able to hold their own with the standard continuously pumped instruments in respect of focus quality, provided ordinary care is taken, and the anode voltage is not too limited.

The net conclusions from these remarks are that (1) the commercially available tubes when operated at about 6-10 kV. can, as Mr. Nethercot has shown, cover a wide range of work in single-stroke transients, although the photographic requirements are quite severe; and (2) that sealed-off tubes can be designed which will compete in all senses with the continuously pumped type, and at a fraction of the cost.

* Messrs. A. C. Cossor, Ltd.

Tracking in Superheterodyne Receivers

Part I

By S. W. AMOS, B.Sc., (Hons).

INTRODUCTION.—Modern superheterodyne receivers use ganged tuning condensers with identical sections for signal frequency and oscillator tuning and the constant difference in frequency, which ideally should be maintained at all settings of the tuning control between the oscillator and signal frequencies, is achieved by appropriate choice of values for the inductance, and the padding and trimming condensers in the oscillator circuit. The maintenance of this constant frequency difference is known as "tracking" and it is the purpose of this article to derive expressions for the value of oscillator inductance and its associated capacitances in various well-known tracking circuits and to discuss their merits and shortcomings. Tracking can only be perfect, *i.e.*, the frequency difference can only equal the chosen intermediate frequency at two or three frequencies in the wave-band, the number of these points depending on the number of variables which can be fixed in the oscillator circuit. If the only variables present are the oscillator inductance and a trimmer condenser, as in some short-wave oscillator circuits, then tracking can only be perfect at two frequencies in the band. To obtain reasonably good tracking over the entire wave-band, these two frequencies should be near—but not too near—the upper and lower limits of the band. It is at these frequencies that the receiver is aligned after manufacture. The trimmer is made variable and is adjusted for maximum amplification at the alignment frequency. If the correct value of inductance has been used then tracking will automatically be perfect at the other end of the band. On the medium and long wave-bands it is customary to use a trimming and padding condenser. With the oscillator inductance there are thus three variables so that three-point tracking is possible. The most convenient scheme is to arrange for perfect tracking at two frequencies, one at each extreme of the wave-band, so that alignment of the receiver is possible by making trimmer and padder variable, and to choose the value of the oscillator inductance so that the third frequency at which tracking is perfect occurs at the middle of the wave-band. At frequencies where tracking is not perfect the signal frequency circuit does not resonate at the received frequency and consequently there is a loss of amplification. Worse still, if the resonant frequency of the RF circuit is higher than the received frequency, then second-channel effects can be very troublesome in a short-wave superhet (it is assumed in this statement, that the receiver follows conventional practice in that the oscillator frequency is higher than the signal frequency), so that considerable thought is necessary in the design of a tracking system to obtain satisfactory results. This article will also deal in some detail with the loss of sensitivity due to misalignment and to the magnitude of second-channel effects in short-wave superhets.

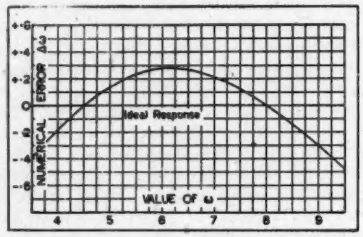


Fig. 2. Variation of numerical error of circuit of Fig. 1. on medium waveband.

Two Point Tracking Trimmer Method

Possibly the simplest type of oscillator tracking circuit is that given in Fig. 1, in which the oscillator circuit simply comprises an inductance L_{osc}, a trimmer C_t in parallel with it and a section C_s of the ganged condenser. The signal frequency circuit contains simply an inductance, L_s, in parallel with another section of the ganged condenser assembly, C_s.

In analyses concerning tuned circuits resonating at radio frequencies it simplifies mathematical considerations considerably to deal with "angular frequencies" (ω) rather than frequencies. We will, therefore, assume throughout this paper that the intermediate frequency is $\frac{\omega'}{2\pi}$ and that the circuits are to be aligned at $\frac{\omega_1}{2\pi}$ and $\frac{\omega_2}{2\pi}$. For the signal frequency circuit we have immediately—

$$\omega_1^2 = \frac{1}{L_s C_1} \text{ and } \omega_2^2 = \frac{1}{L_s C_2}$$

where C_1 and C_2 are the capacitances of C_s corresponding to frequencies of $\frac{\omega_1}{2\pi}$ and $\frac{\omega_2}{2\pi}$ respectively.

Eliminating L_s we have—

$$\frac{C_1}{C_2} = \left(\frac{\omega_2}{\omega_1}\right)^2 \quad \ldots\ldots\ldots\ldots (1)$$

Similar reasoning applied to the oscillator circuit gives—

$$(\omega_1 + \omega')^2 = \frac{1}{L_{osc}(C_1 + C_t)} \quad \ldots\ldots\ldots (2)$$

and

$$(\omega_2 + \omega')^2 = \frac{1}{L_{osc}(C_2 + C_t)} \quad \ldots\ldots\ldots (3)$$

from which, by elimination of L_{osc}, we have—

$$\frac{C_1 + C_t}{C_2 + C_t} = \left(\frac{\omega_2 + \omega'}{\omega_1 + \omega'}\right)^2 \quad \ldots\ldots\ldots\ldots (4)$$

Solving this equation for C_t—

$$C_t = \frac{\omega'(\omega_1 a + \omega_2 b)}{\omega_1^2 \omega_2^2 L_s (a+b)} \quad \ldots\ldots\ldots (5)$$

in which $a = \omega_2 + \omega'$ and $b = \omega + \omega'$.

Knowing C_1 we can calculate L_{osc} from (2) or (3).

Let us calculate suitable values for C_t and L_{osc} for use on the medium waves. We will assume the conventional values for L_s and C_s, namely, 157μH and 500$\mu\mu$F (maximum) respectively. The medium wave-band is generally assumed to extend from 550 kc./s. to 1,500 kc./s.; in terms of angular frequency these extremes are

roughly equivalent to 3.5×10^6 rads./sec. and 9.5×10^6 rads./sec. respectively. It is best not to arrange for perfect tracking to occur precisely at these extreme values, for if this is done a frequency band over which tracking is quite good is lost and the tracking error in the centre of the wave-band is greater than it need be. Better frequencies at which to align are possibly those for which ω is equal to 4.5×10^6 and 8.0×10^6 rads/sec. It is very convenient to take the intermediate frequency as 477.8 kc./s., which is near the common value of 465 kc./s., for this corresponds to a value of ω of exactly 3×10^6 rads./sec. Substituting $\omega_1 = 4.5 \times 10^6$, $\omega_2 = 8.0 \times 10^6$, and $\omega' = 3 \times 10^6$ in (5) we have

$$C_t \doteq \frac{3 \times 10^6 \,(4.5 \times 11 \times 10^{12} + 8 \times 7.5 \times 10^{12})}{157 \times 10^{-6} \times 4.5^2 \times 10^{12} \times 8^2 \times 10^{12} \times 18.5 \times 10^6}$$

$$= 87.7 \ \mu\mu F.$$

Putting this in (2) we find—

$$L_{osc} = \frac{1}{(\omega_1 + \omega')^2 \ (C_1 + C_t)}$$

$$= 44.0 \mu H.$$

Tracking Error—Suppose we wish to calculate the tracking error of this circuit at a particular frequency. As an example consider the frequency for which $\omega = 6 \times 10^6$. At this frequency the capacitance, C_s, in the signal frequency circuit is given by—

$$C_s = \frac{1}{36 \times 10^{12} \times 157 \times 10^{-6}}$$

$$\doteq 176 \ \mu\mu F.$$

This, then, is also the capacitance in the oscillator section of the tuning condenser, but the effective capacitance in this circuit is clearly 176 + 87.7 = 263.7$\mu\mu$F. The oscillator frequency is thus $\frac{\omega_{osc}}{2\pi}$ where—

$$\omega_{osc} = \frac{1}{\sqrt{263.7 \times 10^{-12} \times 44 \ 10^{-6}}}$$

$$\doteq 9.28 \times 10^6 \text{ rads./sec.}$$

The frequency difference is thus 3.28×10^6 rads./sec. Ideally, this should be 3.00×10^6 rads./sec. so that the numerical error, $\Delta\omega$, is + 0.28 rads./sec.

It is convenient to express this as a percentage of the signal frequency: in this example the error is $+ \frac{100 \times .28}{6} \doteq +4.7$ per cent. We will represent the percentage error by $\delta\omega$. The tracking error for various medium wave frequencies is exhibited in tabular form in Table I, which also includes a column for the values of $\frac{\omega}{\omega_1}$, *i.e.*, $\frac{\text{signal frequency}}{\text{lower tracking frequency.}}$

The reason for this inclusion will be apparent later. The numerical error, $\Delta\omega$, for the medium wave-band for the circuit for which the constants have just be evaluated, is plotted in graphical form in Fig. 2. The ideal straight line is also indicated.

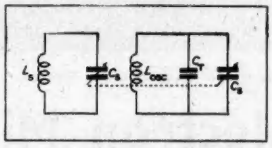


Fig. 1. 'Trimmer' method of superheterodyne tracking.

Loss of Sensitivity due to Tracking Error.

The presence of tracking error causes a loss of sensitivity in a superheterodyne receiver due to mistuning in the signal frequency circuits. Consider the example quoted earlier of a tracking error of + 4.7 per cent. at a signal frequency of $\frac{6}{2\pi}$ mc./s. Here the signal frequency circuits are resonating at $\omega = 6 \times 10^6$ rads./sec. whilst the receiver is tuned, by virtue of its oscillator and intermediate frequencies, to $\omega = 6.28 \times 10^6$. Now, if we postulate a value for the effective Q of the signal frequency circuit (assuming there to be one only) we can assess the magnitude of the tracking error in terms of the loss in sensitivity due to mistuning in this circuit.

The response curve of a single-tuned circuit is expressed by the well-known equation—

$$\frac{\text{response at } df \text{ kc./s. from resonance}}{\text{response at resonance in kc./s.}} = \frac{1}{\sqrt{1 + \frac{4Q^2 \, df^2}{f_0^2}}}$$

where f_0 = resonant frequency.

Let us assume that Q = 100. It is then a simple matter to show that loss in amplification due to mistuning = $10 \log_{10} [1 + 4 (\delta\omega)^2]$ in which $\delta\omega$, as before, is the percentage tracking error.. This applies to any tuned circuit with a Q of 100 resonating at

(*Continued on p.* 422.)

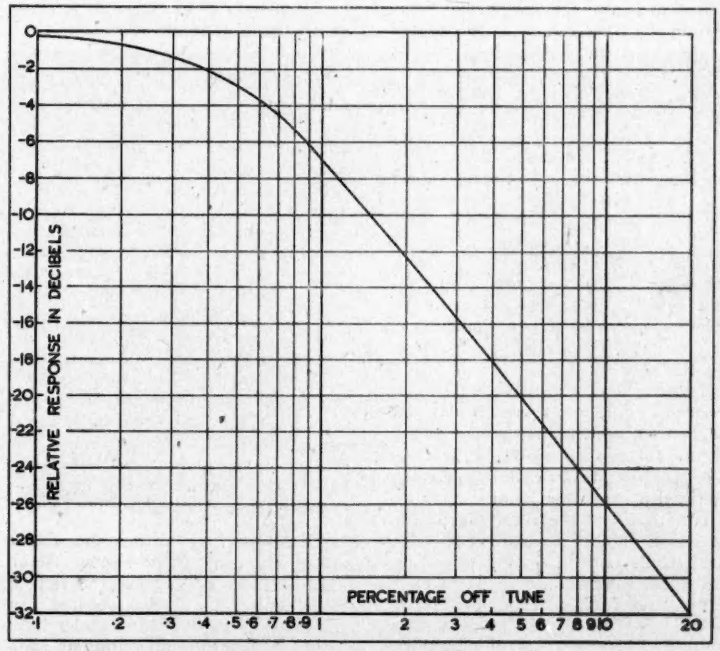


Fig. 3. Response of single tuned circuit with a Q of 100 at various percentages off tune.

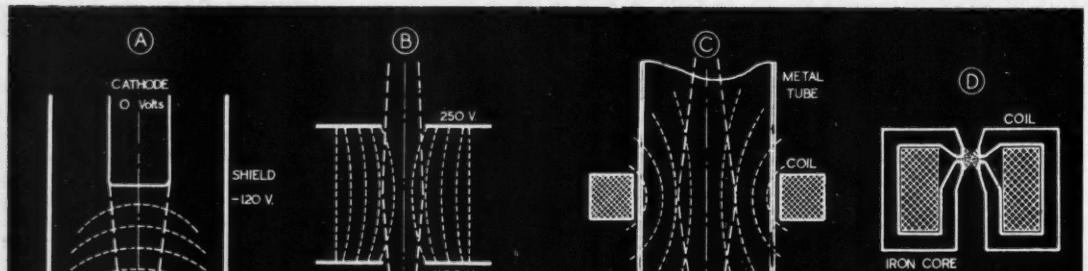


Fig. 1. Four types of electron lens. A & B: Electrostatic, C & D: Electromagnetic.

The Electron Microscope

By W. WILSON, D.Sc., B.Eng., M.I.E.E., M.A.I.E.E.*

No electrical instrument has achieved such sensational results during the past five years as the electron microscope ; for it has effected as great an advance over the performance of the ordinary light microscope as the latter did three centuries ago over the simple magnifying-glass. The author proposes to explain briefly why this improvement has been possible and how it has been brought about ; illustrating the theory by means of successful electron instruments and typical high magnification electron micrograms.

THE wavelength of light is usually regarded as almost infinitely small, and most people are therefore greatly surprised to learn that it is in reality far too large to enable many small articles that have a vital influence on life and industry to be distinguished at all. Actually, the wavelength of blue-green light is 0.5 micron (μ) or 0.005 mm.; and the smallest dimension that can be seen by the human eye is 100μ, or 0.1 mm. Hence it can be readily understood that difficulties arise when magnifications of even ×1,000 or ×2,000 are attempted. By employing invisible ultra-violet light and projecting the image upon a fluorescent screen, and employing quartz lenses instead of glass, a gain of another 50 per cent. or at the very most 100 per cent., may be secured, and this represents the most advanced microscopy that is practicable with rays of light.

Limitations of the Light Microscope

The position can be more precisely described if useful magnification is defined in terms of the resolving power, that is, the ability to show two adjacent particles or lines as two distinct entities; the maximum resolving power, or the "resolving limit," being the smallest separation thus made visible. Then the maximum useful magnification will be the ratio of the resolving power of the human eye (100μ) to that of the lens system concerned. For example, if the resolving limit of a high-class optical microscope is 0.1μ, then the useful magnification is 100/0.1 =1,000.

Now it is well known that the image of a point as seen through a lens system consists of a disk surrounded by diffraction rings, the proportions of which depend upon the wavelength of the light which is being transmitted; a fact which is familiar to users of diffraction gratings, astronomical telescopes and similar optical devices. When the object is large in comparison with the light wave, the effect is inappreciable or unimportant; but it can easily be shown, if the rings be sketched in, that two adjacent points cannot be perceived as distinct entities when their separation is less than about half the wave-length. Thus, however much the image of such a pair be enlarged, they cannot be seen as two points if they are nearer together than the above critical distance.

It therefore follows that the visible light microscope cannot show detail smaller than about 0.25μ, even if greater enlargement be secured, or about half this size if ultra-violet light be employed; although a limited additional gain may be obtained by oblique illumination. But details of such dimensions, implying a useful magnification of only about ×2,000 or ×3,000, are much coarser than many objects, such as dusts in the atmosphere, fibrous constituents of many manufactured products, and disease germs, the examination of which is of the greatest importance, but which can never be made by ordinary light.

Advantage of Electron Stream

Users of the cathode-ray oscillograph are well aware that the stream of electrons emanating from the cathode and constituting the cathode-ray beam can be refracted by either a magnetic or an electric field, for every modern instrument of this type is provided with a "concentrating" coil, or with a succession of electrodes maintained at different voltages, in order to focus the spot. But it was not realised until 19 years ago that a travelling electron has a definite wavelength, the value of which was shown by de Broglie to be

$$= \sqrt{(150/E)} \times 10^{-10} \text{ metres} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$= \sqrt{150/E} \text{ Angstrom units,}$$

where E is the accelerating or "anode" voltage. The value of E for large metal-tube oscillographs is frequently 60,000 volts, which will be seen to produce a wave-length of $.05 \times 10^{-10}$ metres $0.5 \times 10^{-4}\mu$. That is, quite usual

* The General Electric Co. Ltd.

cathode-oscillograph practice will give a wavelength equal to 10^{-5} that of the blue-green light already mentioned, which is situated very near the favourable end of the visible spectrum. Hence the useful magnification when an electron stream is substituted for visible light may be increased as much as 100,000 times. It will be seen therefore, that the epithet "sensational," which was used to describe the capabilities of the instrument, is fully justified.

It is true that only a small fraction of this enormous extension has as yet been found practicable. Electron lenses are subject to aberrations and other peculiarities, just as in the case of their glass equivalents, and much research will be necessary before the maximum advantage can be obtained from their use. For the present, it is sufficient to say that chromatic and spherical aberrations have been so controlled that magnifications 100 times as great as those given by the light microscope have already been secured, increasing the advantage over the naked eye from 2,000 to 200,000 diameters.

Electron Lenses

Electrons are charges of negative electricity, and are therefore attracted or repelled by an electrostatic field; while since a travelling negative charge constitutes an electric current, the electron stream is also subjected to a transverse force by a magnetic field. Either field can therefore refract the beam, and any arrangement of lines of electric or magnetic force possessing axial symmetry will function as a lens. Examples of electron lenses which have for years been used as components in cathode oscillographs are shown in Fig. 1.

The first two are electrostatic lenses used in many glass cathode-ray tubes. That on the left, A, is the condenser-lens formed by the cathode cylindrical shield and the gun electrode, which are maintained at different voltages as shown. Equipotential surfaces are shown by the lines in the diagram, which "condense" or concentrate the electron stream as indicated by the dotted lines and cause much more of it to pass through the aperture than would otherwise be the case.

To the right is shown a two electrode "lens" (B) employed in a high-vacuum glass tube for focusing the spot on the fluorescent screen. Again, the electrodes are maintained at different voltages, and the electrons cut the curved flux, with the result illustrated. A third electrode, often in the form of a tube, is usually interposed between them, and connected to an intermediate voltage.

Two electro-magnetic lenses are shown after these. On the left (C) is the "concentrating coil" fitted on the outside of the metal-tube type of oscillograph. A symmetrical magnetic flux is produced which, by cutting the electron stream, is able to bend the rays towards each other. Focusing is adjusted by means of a rheostat varying the exciting current.

The remaining figure (D) illustrates an "ironclad" concentrating coil, in which an almost complete iron path is provided for the flux. Only a small air gap is left, across which an intense flux passes, capable of exerting a very strong focusing effect upon the beam.

A great deal of research is being carried out at the present time on the exact design of these lenses, particularly the last pattern, in order to overcome spherical aberration. Present-day electron microscopes using this form of lens are provided with extremely small apertures (diaphragms) of the order of 0.02 mm. diameter, sacrificing over 99 per cent. of the illumination in the interest of definition, and incidentally helping to secure a great depth of focus. It is for the latter reason that the whole of the object in an electron micrograph is in sharp focus, and not merely one thin plane, as in the "light" instrument. This is exemplified very clearly in the examples given later.

Types of Electron Microscope

There are three distinct types of electron microscope, namely, one using electrostatic lenses and usually having a glass tube; one using electro-magnetic lenses with a metal tube; and a "scanning" type. The last-named closely resembles in principle the television camera and receiver, in that a very small cathode spot (less than 10^{-6} in. in diameter) is traversed over the object, and a greatly amplified image is projected on the fluorescent screen of a receiving oscillograph. Only moderate magnifications of the order of 3,000 to 8,000 diameters have hitherto been

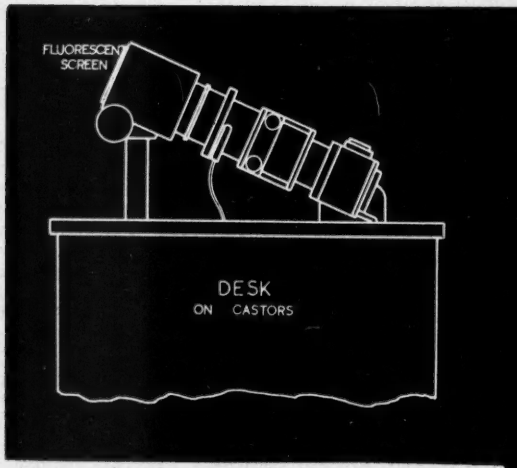


Fig. 4. The R.C.A. Desk pattern Electron Microscope

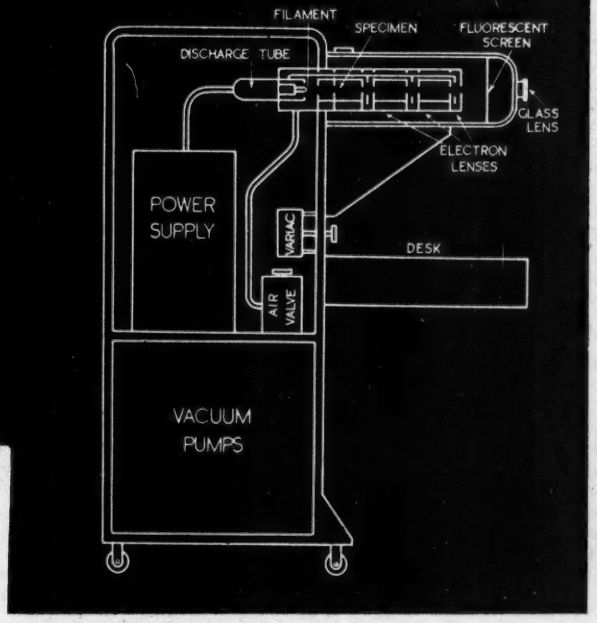


Fig. 5 (right). G.E. Electron Microscope: Sectional elevation showing the electrostatic lenses.

achieved by this form, regarding which nothing further need here be said.

The magnetic tube is that which has been responsible for the highest magnifications, and is at present the most widely used. Successful examples have been designed and made in Central Europe, Belgium, England, Canada and the United States; and since the last-named, by the R.C.A. of Camden, is the latest and in many ways the most advanced pattern, and moreover the first to be manufactured on a production basis, it will be described in some detail.

R.C.A. Floor Model

The best-known form, which appeared only in April, 1941, is shown in Fig. 2. It consists of a vertical tube about 6 ft. high from cathode to base, with three lenses of the general type illustrated in Fig. 1D inserted in the tube. These lenses correspond to those in the ordinary light microscope as set up for projection or photography, the equivalent optical components being shown diagrammatically on the left; the arrangement having the illuminant at the top and the screen and plate at the bottom, which is more common with the photographic enlarger than the microscope proper. Whatever the position, a sub-stage condenser comes after the light source and before the object, after which is the objective followed by the eye-piece or projecting lens. Both electron and optical lenses have exactly the same functions in all three cases.

In order to show the actual form of the electronic components, an enlarged photograph and section of the part of the tube containing the condenser, object-holder, and objective lens are given in Fig. 3. The difference between the wide aperture condensing lens and the small aperture short focus objective is very marked. It will also be observed that the iron bodies of the lenses form part of the tube, on to which they fit through the medium of vacuum-tight broad flange joints, lagged with neoprene synthetic rubber. For evacuation purposes, the various sections are connected to the three-stage oil diffusion pumps backed by mechanical pumps, situated in the base of the instrument, by means of the " manifold " bus-pipe on the right of the main tube.

Air locks are used to introduce the " object " and the photographic plate into the tube, without having to release and then recreate the vacuum in the whole enclosure, the normal value of which is about 10^{-5} mm. The photograph shows the process of inserting the tube-shaped object-holder. To enable this to be done, a handle at the back of the tube is first operated to raise the object support from just above the lens aperture and to shut off the main chamber, after which a second handle admits air to the lock chamber and then opens the trap-door. The photo-plate lock is seen just below the bench-top in Fig. 2. It has to deal with a glass plate 2 in. wide by 10 in. long, upon which a series of photographs, usually 2 in. by 2 in., is exposed.

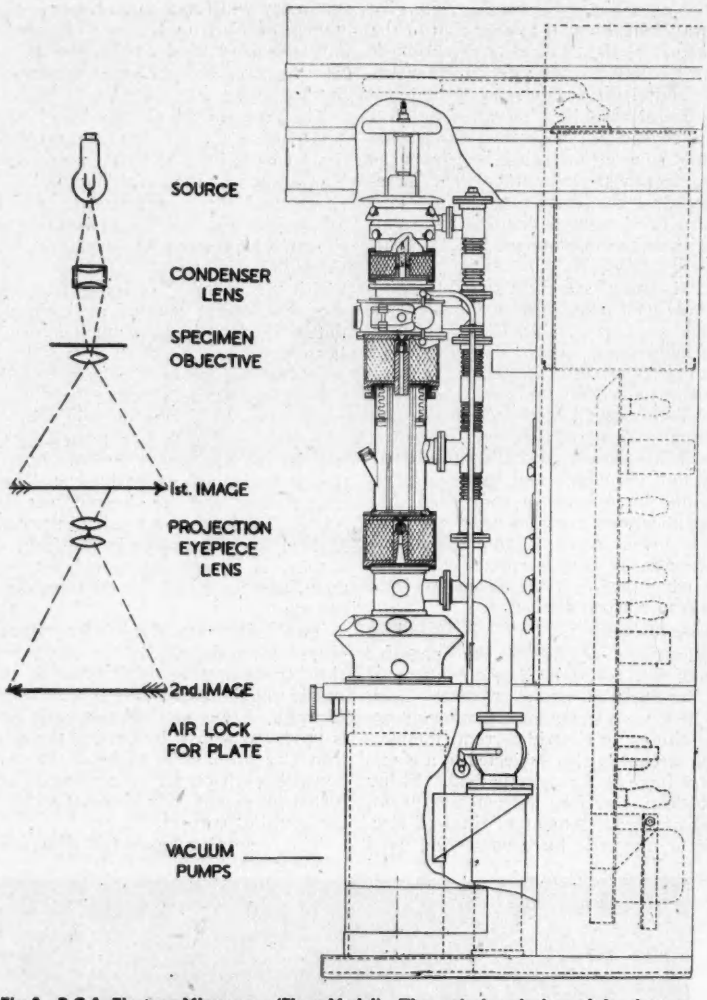
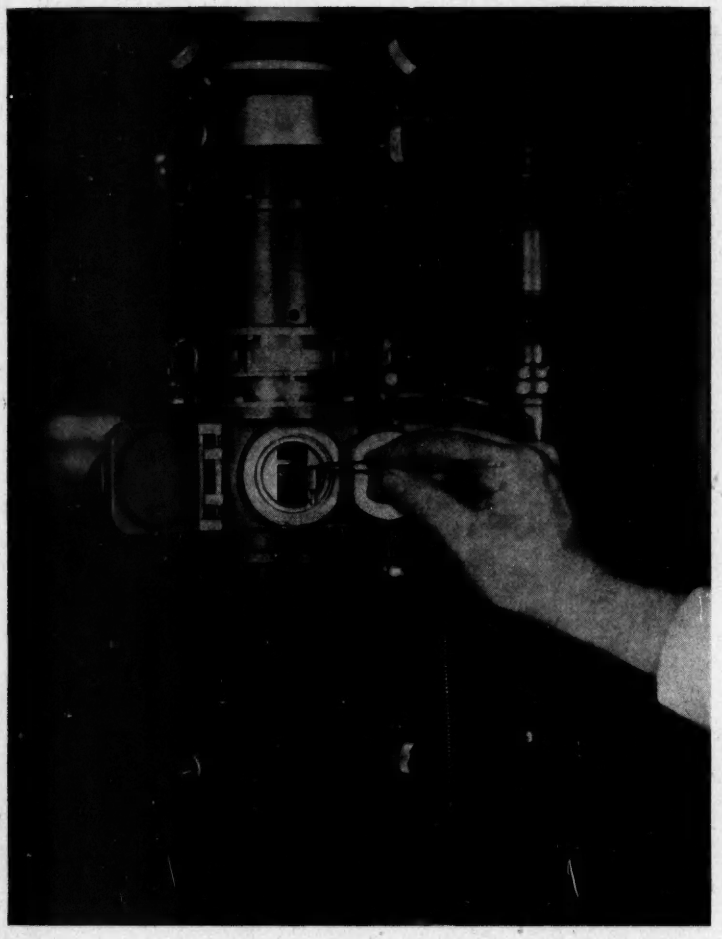


Fig. 2. R.C.A. Electron Microscope (Floor Model). The optical equivalent of the electron lens system is shown on the left.

The supply of high voltage for the anode is carried out in rather a novel manner. Since the wavelength of the electrons depends on this voltage in accordance with equation (1), and since rays of different wavelength come to a focus at different points, a sharply defined image can only be secured if all the rays have the same wavelength. To use an optical expression, a simple lens will give rise to chromatic aberration unless the beam is monochromatic. Instead of deriving the D.C. at 60 kV. by transforming and rectifying mains frequency power, therefore, an oscillator giving 32,000 c/s. is employed, the very high frequency enabling extremely effective filtering, smoothing and screening to be carried out without requiring large-capacity condensers. A feed-back regulator stabilised by a standard voltage source obviates long period fluctuations.

The focus of the electron lenses is also dependent upon the voltage applied to the coils, and is in fact adjusted by voltage variation and not by moving the position of the lenses, as with the light microscope. Constancy is obviously just as important for the supply to the lenses as for that to the anode; and the same method of



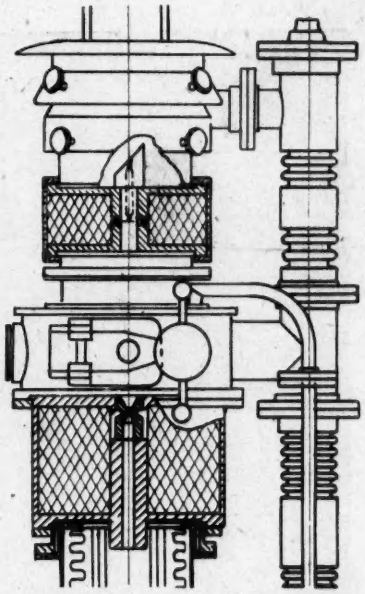


Fig. 3. Two electron lenses and air-lock of the R.C.A. electron microscope. Photograph corresponding to the sectional view shown. The condenser lens is just above and the objective lens is just below the air-lock. Note the specimen holder in the forceps.

smoothed H.F. is adopted. A variation of only 0.002 per cent. is achieved for the anode and objective-lens voltages, and 0.004 per cent. for the projection lens.

As the instrument is to be used by many non-electrical people, it is essential that all H.V. parts be effectively enclosed. Accordingly the cathode is shielded by the overhead canopy, and the H.V. transformer is contained in an oil-tank situated in the upper part of the cubicle at the back of the tube. Below are valves numbering about fifty, condensers, resistors, and other electronic accessories, while on the panel in the front of the cubicle, and convenient to the operator, are the control knobs and meters.

There are two sets of viewing ports. Three are located above the projection lens, in Fig. 2, for examining the "first" image, and six just above the photographic plate and main fluorescent screen for viewing the final, most highly magnified image; three operators, using a pair of ports each, thus being able to study the object simultaneously. The screen can be rotated away from the path of the rays, and then acts as a shutter for exposing the plate.

The mounting of the objects calls for a more exacting technique than is needed for light microscope slides. As cathode-rays are stopped by any material much thicker than 10^{-6}., the final support of the specimen is a thin film of nitro-cellulose of not more than this thickness. The film is attached to a fine metal gauze disk having 200 meshes per linear inch by first allowing a drop to spread out on water, and placing the disk upon it. Then the specimen is suspended in liquid, a drop of which is placed on the film and allowed to evaporate; and, finally, the disk is carefully placed in the tubular holder, not quite an inch long, which is seen in the tweezers in Fig. 3.

R.C.A. Desk Model

A smaller and simpler form of electron microscope has been produced by the R.C.A. organisation during the past twelve months. For many situations the high capabilities and wide range of magnification of the type just described are not necessary. Many industrial and research situations are adequately served by a fixed magnification of 5,000, with the possibility of increase by photographic enlargement of as much as twenty times to 100,000 diameters without exhausting the detail in the original negative. This performance is given by the desk pattern of instrument shown in Fig. 4.

Here the length of the tube is only 16 in., and the anode voltage is reduced to 30 kV. Since so small a tube can be evacuated in about two minutes, air-locks are unnecessary.

The objective and projector lenses are energised by one coil and are situated in the smaller part of the tube, from which the flexible connexion is seen coming down. No condenser lens is fitted other than the cathode shield, which functions as in Fig. 1A. A thick glass fluorescent screen occupies the end of the tube and is viewed through the glass from the outside. Both the evacuating equipment and the electrical gear are inside the desk.

G.E. Electrostatic Model

An interesting microscope employing electrostatic lenses has been recently

(*Continued on p. 420.*)

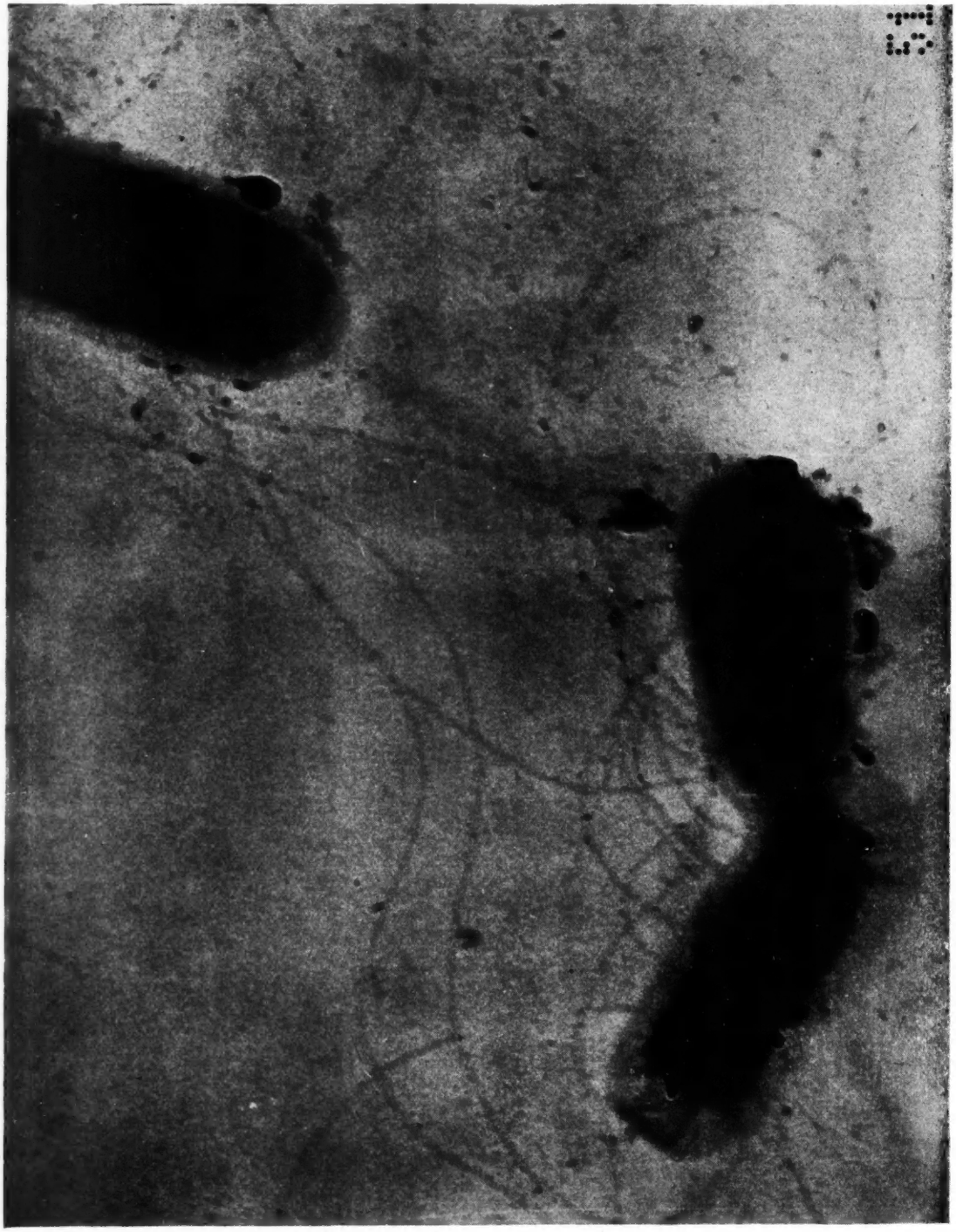


Fig. 6. Electron Micrograph of Aerobacterium Cloacæ (bacillus of the lower intestine) (x 54,000).

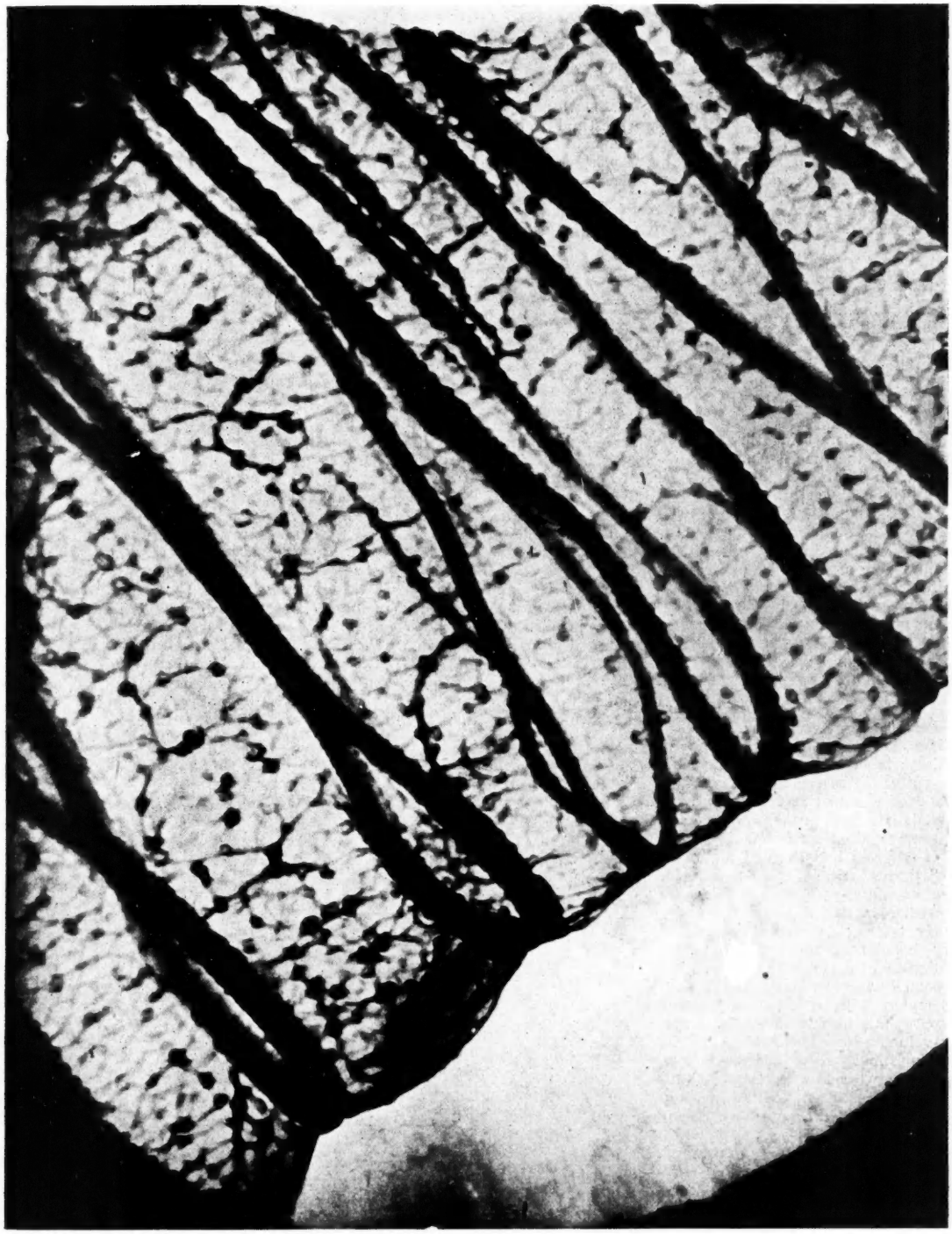


Fig. 7. Portion of Trachea (Windpipe) of Honey Bee (x 25,000).

constructed by the G.E. Co. of America. The three-diaphragm type of lens has been adopted, as illustrated in Fig. 5, and increased magnification has been secured by employing more than the conventional number (2) of stages for the lens system.

The tube is arranged horizontally, and the last stage of magnification is by a glass lens, by which the image in the fluorescent screen is viewed. An important advantage of the electrostatic lens is that fluctuations of voltage can be made to produce equal and opposite effects upon the focus, first by altering the acceleration of the electrons, and secondly by modifying the focal lengths of the lenses. The power supplies to the anode and to the lenses can therefore be quite unregulated, and one of the chief sources of complication in the usual design thus eliminated. For obtaining a photographic record, a camera is substituted for the lens.

In spite of there being three electrostatic lenses, the tube is short, the distance from filament to fluorescent screen being only 11 in. For so small a volume, relatively simple pumping equipment is sufficient to create the necessary vacuum in two minutes. A magnification of ×500 is obtained by electronic means, the remainder coming from optical or photographic enlargement, up to a total of from ×3,000 to ×8,000. Smooth control of the anode voltage is afforded by the Variac regulator, up to a maximum of about 35 kV.

Examples of Electron Micrography

There is no need to stress the epoch-making advances that are taking place as a result of the sudden extension of knowledge due to this instrument. In many, if not most branches of science, there were numerous sub-classes in which progress had reached a " dead-end " through the inability to perceive the ultra-microscopic objects that were involved. Now that large molecules can already be seen, there would appear every hope that these long-standing questions will be answered in full. A few examples, recorded by the R.C.A. instrument, will be given of electron micrographs which have yielded especially valuable information.

No questions are of greater importance to man than those relating to his health. It has been well known for many years that diseases were due to extremely small bodies, some of which were large enough to detect; but many, including the viruses of the common cold and influenza, were unknown. Now they can not only be seen, but in a number of cases their body structure, and the process involved in their destruction, can be witnessed. Two bacilli of a disease of the lower intestines. *Aerobacterium Cloacae*, 54.000 their actual tize, are shown in Fig. 6, in which the structure and the long flagella are clearly seen. A striking example of this category was published in ELECTRONIC ENGINEERING, July 1943, in which another intestinal bacillus, *Escherichia Coli*, is seen being attacked by a crowd of small bacteriophages, the anti-bodies present in the human system that are able to defeat infection. Other micrographs have been taken which enable the malignant germs to be viewed at all stages of disintegration, some being half removed from their outer shell and others with the capsule empty beside them.

A biological micrograph is shown in Fig. 7, being a portion of a bee's windpipe, in which the arrangement of the blood-vessels and canals is clearly visible.

Much work has been done within recent years upon the constitution, particle size, and effects of dust and smoke. Their influence upon health, upon the occurrence of fog and upon the functioning of bearing surfaces and other mechanisms, as well as economy in the use of fuel, have all been the subject of prolonged research. The dendritic crystals shown in Fig. 8 are composed of zinc oxide and constitute the smoke formed when the metal is burnt in air. They consist of four spicules (thin spikes) united in the centre of the dendrite.

A specially valuable proceeding is the examination of materials before they are made up in order to predict their performance without requiring a " try-out " in practice. Two examples may be mentioned in which magnifications of about 50,000 enabled the fitness of certain powders for their work to be studied. The first was one form of an insecticide consisting of lead arsenate powder, which was found to give much better results in practice than an apparently similar powder from another source. The micrograph revealed that the former variety was composed of minute plates of extreme thinness, and therefore possessed much greater covering power than its rival. The second was a sample of Aragonite possessing unusual chemical activity. Again the micrograph provided the reason, namely, the presence of corrugations and pores in the particles, which afforded a large surface area to the reagents.

Conclusion

The electron microscope has been shown in this short article to have enabled the magnification of very small objects to be increased a hundredfold, i.e., from 2,000 to about 200,000. A few examples out of the many that have already been obtained have served to indicate the amazing results that may be expected from the new instrument in the near future. But when it is realised that the wavelength of the electron stream would permit a further increase of up to a thousandfold if the various aberrations of the lens system can be sufficiently reduced, one can only look forward with awe to the revelations to come.

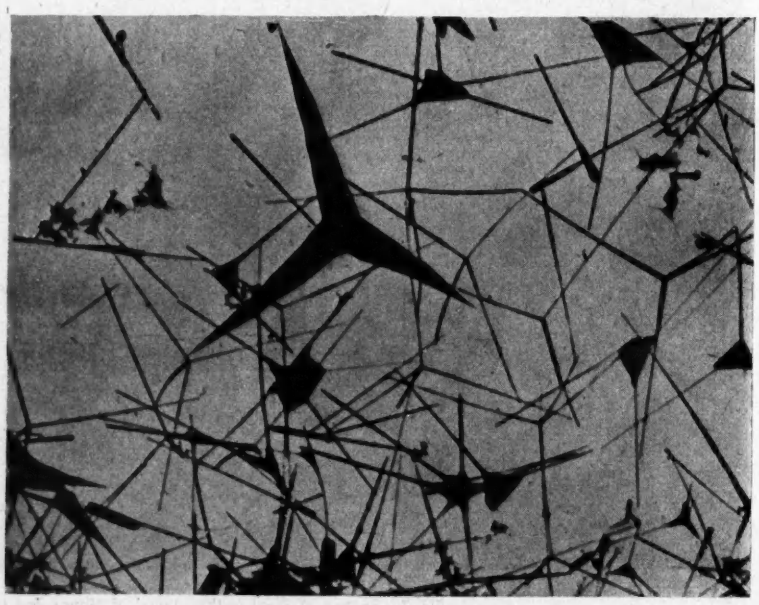
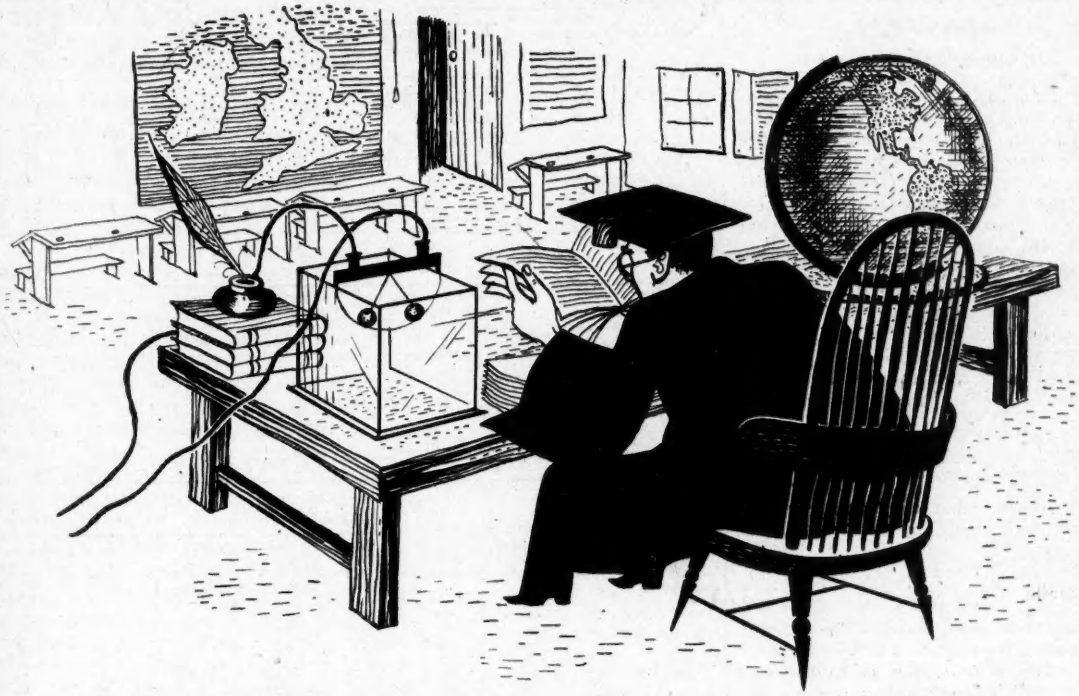


Fig. 8. Crystals constituting Zinc Oxide smoke (x 30,000).



10 out of 10, Mr. Canton!

John Canton was a London schoolteacher in the eighteenth century. Perhaps as a relief from giving daily instruction in the 3 R's, he himself turned scholar and learned all he could out of school hours about the then obscure subject of electricity. With few resources, he eventually made the first pith ball electrometer, and read a paper before the Royal Society on his method of producing artificial magnets. For this he was elected a Fellow and awarded the Copley medal.

We think that John Canton would have given Distrene (Regd.) 10 out of 10 for its outstanding insulating and electrical properties. The brief data below can be checked against the working samples; may we send them? Distrene is made in sheets, rods and tubes, and also as a moulding powder for injection machines. You get more mouldings per pound of Distrene than with any other plastic because of its low density and faster moulding rate.

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COMPRESSION STRENGTH	7 *tons per sq. in.*
SPECIFIC GRAVITY	1·06
WATER ABSORPTION	*Nil*
COEFFICIENT OF LINEAR EXPANSION	·0001
SURFACE RESISTIVITY (24 hours in water)	3×10^6 *megohms.*
DIELECTRIC CONSTANT 60—10^6 CYCLES	2·60—2·70
POWER FACTOR UP TO 100 MEGACYCLES	·0002—·0003

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LH/BX 197

Tracking in Superheterodyne Receivers

(*Continued from p.* 413.)

any frequency providing the degree of mistuning is not too great. This expression has been plotted in the form of a graph in Fig. 3. From this, using the same tracking circuit as before as an example, it is immediately apparent that the +4.7 per cent. tracking error gives a loss of sensitivity of 19.5 db, a serious loss. A complete picture of the performance of this circuit over the medium wave-band is given in Fig. 4, in which the loss in sensitivity obtained from Fig. 2 and the values of $\delta\omega$ given in Table I, has been plotted against $\frac{\omega}{\omega_1}$. $\frac{\omega}{\omega_1}$ was chosen in preference to ω so that curves for other wave-bands could be superposed in the same diagram to permit immediate comparisons of performance to be made.

Long Wave Performance.—The long wave-band may be deemed to extend from $\omega = .95 \times 10^6$ to $\omega = 1.9 \times 10^6$, which is equivalent roughly to 150 – 300 kc./s. If we choose the alignment frequencies at $\omega_1 = 1.2 \times 10^6$ and $\omega^2 = 1.65 \times 10^6$, we have, using the standard value of long-wave signal frequency inductance, L_s, as 2,000μH, from (5)—

$$C_t = 490\mu\mu F.$$
$$L_{osc} = 70.4\mu H.$$

As before the performance of the circuit is illustrated in tabular form in Table II. The loss in sensitivity due to misalignment is indicated in Fig. 4, and this was calculated from the last column of Table II and Fig. 2.

TABLE I

Value of ω ($\times 10^6$ rads./sec.)	Value of $\frac{\omega}{\omega_1}$	Value of C_s ($\mu\mu F$)	Value of C_{osc} ($\mu\mu F$)	Value of ω_{osc} ($\times 10^6$ rads/sec)	Value of $\omega_{osc}-\omega$ ($\times 10^6$ rads./sec.)	Value of $\Delta\omega$ ($\times 10^6$ rads./sec.)	Value of $\delta\omega$ (per cent.)
3.5	.77	520	608	6.11	2.61	−.39	−11
4.0	.90	398	486	6.84	2.84	−.16	−4
4.5	1.00	315	403	7.50	3.00	0	0
5.0	1.11	255	343	8.14	3.14	+.14	+2.8
5.5	1.22	210	298	8.72	3.22	+.22	+4.0
6.0	1.33	176	264	9.28	3.28	+.28	+4.7
7.0	1.55	130	218	10.21	3.21	+.21	+3.0
8.0	1.77	99.5	188	11.00	3.00	0	0
9.0	2.00	78.6	166.6	11.70	2.70	−.3	−3.3
9.5	2.11	70.6	158.6	11.97	2.47	−.52	−5.7

TABLE II

Value of ω ($\times 10^6$ rads./sec.)	Value of $\frac{\omega}{\omega_1}$	Value of C_s ($\mu\mu F$)	Value of C_{osc} ($\mu\mu F$)	Value of ω_{osc} ($\times 10^6$ rads./sec.)	Value of $\omega_{osc}-\omega$ ($\times 10^6$ rads./sec.)	Value of $\Delta\omega$ ($\times 10^6$ rads./sec.)	Value of $\delta\omega$ (per cent.)
0.95	.792	504	994	3.78	2.83	−.17	−17.9
1.00	.83	454	944	3.96	2.96	−.04	− 4.0
1.20(ω_1)	1.00	316	806	4.20	3.00	0	0
1.40	1.167	232	722	4.44	3.04	+.04	+2.6
1.60	1.33	178	668	4.61	3.01	+.01	+.81
1.65(ω_2)	1.375	167	657	4.65	3.00	0	0
1.80	1.50	140	630	4.75	2.95	−.05	−2.9
1.90	1.58	126	616	4.80	2.90	−.1	−5.2

TABLE III

Value of ω ($\times 10^6$ rads./sec.)	Value of $\frac{\omega}{\omega_1}$	Value of C_s ($\mu\mu F$)	Value of C_{osc} ($\mu\mu F$)	Value of ω_{osc} ($\times 10^6$ rads./sec.)	Value of $\omega_{osc}-\omega$ ($\times 10^6$ rads./sec.)	Value of $\Delta\omega$ ($\times 10^6$ rads./sec.)	Value of $\delta\omega$ per cent.	Second channel ratio (dbs.)
38	.95	492	500	40.9	2.9	−.1	−.26	−28
40(ω_1)	1.00	444	452	43.0	3.0	0	0	−29
50	1.25	284	292	53.5	3.5	+.5	+1.00	−21
60	1.50	197	205	63.85	3.85	+.85	+1.42	−18
70	1.75	145	153	74.0	4.00	+1.0	+1.43	−17
80	2.00	111	119	83.9	3.90	+.90	+1.08	−17
100(ω_2)	2.50	71	79	103.0	3.00	0	0	−21
113	2.83	55.6	63.4	114.8	1.80	−1.2	−1.06	−11.5

Short Wave Performance.—Assuming that the short wave-band extends from $\omega = 37.7 \times 10^6$ to $\omega = 113 \times 10^6$ (roughly equivalent to 6 – 18 mc./s.) we can align at $\omega_1 = 40 \times 10^6$ and $\omega_2 = 100 \times 10^6$. This wave-band, which, it will be noted, has a ratio of maximum to minimum frequency of 3 : 1, can usually just be covered using a standard tuning condenser of 500$\mu\mu$F. maximum capacitance and and inductance, L_s, of 1.408μH. Substituting for ω_1, ω_2 and ω', and L_s in (5) we have—

$$C_t = 7.81\ \mu\mu F.$$

from which $L_{osc} = 1.196\mu H$.

In preparing Table III, which describes the short-wave performance of this circuit, an additional column has been introduced. This has been done because of the presence of second channel effects, which were negligible on medium and long waves, but can be very serious on the short wave-band. A circuit with a Q of 100, resonating at 1,000 kc./s., will have a very poor response indeed at 1,955 kc./s., and it is on this frequency that signals can cause second channel interference. A circuit with the same Q value tuned to, say, 18 mc./s., will have an appreciable response at 18,955 kc./s.; in fact, as this represents 5.3 per cent. mistuning, we can say, from Fig. 3, that the relative intensity of the second channel signal, assuming it to be of the same carrier strength and modulation level as the wanted signal, will be −21 db compared with the wanted signal. The additional column in Table III expresses the relative intensity of the unwanted signal com-

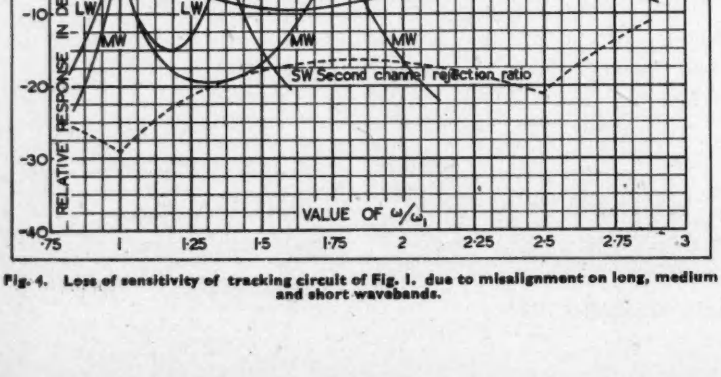


Fig. 4. Loss of sensitivity of tracking circuit of Fig. 1. due to misalignment on long, medium and short wavebands.

pared with that of the wanted one, in terms of decibels. The value of this ratio is also indicated by the dotted curve in Fig. 4.

Practical Considerations—From Fig 4 it is quite evident that this particular type of tracking circuit is only suitable for use on short waves, for the loss of sensitivity due to tracking error on long and medium waves is so serious that good sensitivity is only possible over a small frequency range surrounding the alignment points. On short waves, however, the greatest loss is 9 db and the second channel effects are generally about 20 db down compared with the wanted signal. This is true only if a circuit with a Q of 100 precedes the frequency changer. Both these figures, and the overall sensitivity of the receiver, would be reduced by the use of a circuit with a Q of less than 100

Practical curves are liable to differ somewhat from those given in Fig. 4, mainly because of the assumption made earlier that the capacitances of both sections of the ganged tuning condenser are identical at all settings of the tuning control. This will not, in general, be true because some capacitance will be "reflected" into the preselector circuit from the aerial and, of course, stray capacitances are never the same in any two nominally similar circuits. The advantage of making C_t variable is that it can be adjusted at the alignment frequency:

(a) to add just sufficient capacitance to the oscillator circuit to make the two sections of the ganged condenser of effectively the same capacitance,

(b) to add, in addition to the capacitance mentioned in (a) the calculated value of C_t to give correct tracking.

As, however, the capacitance reflected from the aerial is a function of frequency, this adjustment will only hold accurately for the frequency at which it is made. If care is taken to reduce the reflected aerial capacitance to small dimensions the effects of it on the tracking will not be very great. Both of the adjustments indicated at (a) and (b) are achieved simultaneously by adjusting C_t experimentally so that the receiver gives maximum amplification at one (usually the higher) of the two alignment frequencies.

(To be concluded.)

MARCH MEETINGS

Institution of Electrical Engineers

Wireless Section

At the meeting to be held on March 1 at 5.30 p.m., a paper will be given by A. J. Maddock, M.Sc., entitled "Some Applications of Thyratrons in Radio Engineering."

On Tuesday, March 21 at 5.30 p.m., a Discussion will be held on "Treatment and Tests for Extreme Climatic Conditions" and will be opened by E. M. Lee, B.Sc.

Informal Meeting

On March 20 at 5.30 p.m., a Discussion will be held on "Industry's Opportunity in Education" and will be opened by P. Dunsheath, O.B.E., M.A., D.Sc.

Students Section

The next meeting of the above will be held on March 15 at 6.30 p.m. at the Institution of Electrical Engineers, London, W.C.2. The lecture will be given by H. W. H. Warren, M.Sc., on "Electrical Engineering Research."

Cambridge Wireless Group

The Council of the Institution of Electrical Engineers have sanctioned formation of a Wireless Group in Cambridge. The officers are:

Chairman of Committee, Mr. C. R. Stoner, B.Sc.; Vice-chairman, Mr. B. J. Edwards; Hon. secretary, Mr. D. I. Lawson, M.Sc.

The inaugural meeting was held on February 17th, when Mr. T. E. Goldup repeated his Chairman's address to the London Wireless Section. Particulars of the Group can be obtained on application to the Hon. Secretary Messrs. Pye Radio Ltd.

Brit. I.R.E.

The meeting to be held on March 30 will take the form of a Discussion on "Design for Quality Reproduction," and will be opened with an address by Dr. Malcolm Sargent. The meeting will commence at 6.30 p.m. at The Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1.

Association for Scientific Photography

The next meeting will be held on March 25 at 2.30 p.m., at The Caxton Hall, Westminster, London, S.W.1. Two papers will be read as follows:—"General Theory of Lens Performance," by A. Cox, B.A., B.Sc., A.Inst.P. "Lens Types and their Characteristics," by H. W. Martin, A.R.P.S.

British Kinematograph Society

On March 8 at the Gaumont-British Theatre, Film House, Wardour Street, London, W.1, at 6 p.m., and a paper will be given by Michael Balcon on "Post-War Planning."

Institute of Physics

Electronics Group

The next meeting of the above Group will be held on March 2 at 5.30 p.m. in the Reid-Knox Hall of the British Institute of Radiology, 32, Welbeck Street, London, W.1. Dr. F. C. Toy of the Shirley Institute, Manchester will lecture on the "Electron Microscope."

Industrial Radiology Group

On March 18 at 2.30 p.m. the meeting will take the form of an open Discussion on selected questions. The meeting will be held at the Chelsea Polytechnic, Manresa Road, London, S.W.3.

Institution of Electronics

The next meeting of the above will be held on Friday, March 10 at 6.30 p.m. at the Reynolds Hall, College of Technology, Manchester. The lecture will be given by A. H. McKeag, M.Sc. (of the G.E.C. Ltd., Wembley) on "Recent Developments in Luminescence with particular reference to Discharge Lamps." Tickets may be obtained on application to Mr. L. F. Berry, 14, Heywood Avenue, Austerlands, Oldham, Lancs.

London Section

A meeting will be held on Saturday, March 18, at 3 p.m., in the Rooms of the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2. A lecture will be given on "Thermionic Valve Rectifiers: Design and Application, by F. E. Henderson, A.M.I.E.E., of the G.E.C., Ltd.

Electronic Music Group

The next meeting will be held at the Northern Polytechnic Institute, Holloway Road, N.7, on Saturday, March 4, at 2.30 p.m., when the results of the recent questionnaire will be discussed and the programme of future meetings decided.

The Television Society

Resignation of Mr. J. J. Denton

At the annual general meeting of the Television Society, held at the Institution of Electrical Engineers, on February 5, members heard with deep regret that Mr. J. J. Denton, the Hon. Secretary, had felt it necessary to give up his office on account of his advancing years.

Mr. Denton was one of the four founder members of the Society and has served it for seventeen years as Hon. Secretary. He made it his hobby and devoted nearly all his spare time to fostering interest in television in the early days.

A New Discovery in Physics??

Ehrenhaft's Magnetic Current

THE daily Press of Jan. 17th, carried paragraphs announcing from New York, the discovery of the existence of a pure magnetic current by Prof. F. Ehrenhaft.

The results of the experiments were presented to the American Physical Society, and in the discoverer's reported words:

"If the ends of a piece of pure soft iron are immersed in acidulated water, pure hydrogen is evolved. However, as soon as the ends of this piece of iron are magnetised north and south, no longer is pure hydrogen evolved. Instead, we get a mixture of hydrogen and oxygen, or 2-12 per cent. oxygen. The gas bubbles bearing a magnetic charge opposite in sign to the respective poles are retained thereon, while the gas bubbles bearing a like sign are repelled, even against the force of buoyancy.

This appearance of oxygen shows that the water has been decomposed. The decomposition of water by the Voltaic cell, proved the existence of the electric current, so likewise the decomposition of the water by the magnet, proves the existence of the magnetic current."

Other experiments were described, including one which showed that the pole strength of a permanent magnet decreased during the above process.

In view of these revolutionary claims, which, according to the *Times* correspondent, rank in importance with the discovery of the principle of the dynamo by Faraday, the subject has been investigated by J. T. Kendall of the Research Department, Metropolitan-Vickers Co., and his results are published below, by permission of the Editors of *Nature*:

"The account of Ehrenhaft's claim to have discovered a magnetic current, which appeared in the daily Press of January 17, is very brief and possibly inexact. However, it appeared to be so completely contrary to the fundamental conceptions of electricity and magnetism, that thoughtful readers must search their minds for other interpretations of the experimental phenomena he is reported to have observed. Accordingly, we at once set up apparatus to repeat the experiments which the Press had described.

"The soft iron pole-pieces of a powerful electro-magnet were immersed in dilute hydrochloric acid. The pole-pieces were soldered to a brass block to ensure that the experiments could not be vitiated by the passage of unsuspected leakage currents through the liquid. A fine stream of bubbles was given off at each pole, and when the magnetising current was switched on, the streams of bubbles tended to be deflected into the space between the poles, which was 1.5 mm. wide. Some of the bubbles were deflected downwards, against their buoyancy. Close observation showed that the motion of the bubbles was apparently caused by the motion of the liquid as a whole. Small inequalities of concentration, which are shown up as refractive index striations, permit any motion of the liquid to be recognised. Under the influence of the magnetic field, a steady streaming of the liquid from the pole faces into the centre of the gap and the consequent setting up of rotary currents in the liquid were observed. The streams of bubbles were entrained and carried along with this movement, and their motion was mainly controlled by it.

"Confirmation of this motion of the liquid was obtained by repeating the experiment with the pole-pieces covered with a film of paraffin wax, and immersed in a solution of ferrous chloride. Under these conditions no bubbles were formed and no movement of the liquid in the magnetic field took place. However, if water was slowly poured into the solution, thus providing a non-uniform concentration of ferrous chloride, movement of the liquid in the magnetic field did occur. If the addition of water was stopped, the motion gradually died away as the concentration of ferrous chloride regained uniformity.

"The movement of the liquid under the conditions above described can be explained very easily. It is due to the action of the strong, non-uniform magnetic field on the non-uniform concentration of para-magnetic ferrous ions. The parts of the liquid containing a high concentration of ferrous ions will tend to move in the strongest parts of the field. In confirmation of this, a number of other electrolytes were tried, both with waxed and unwaxed pole-pieces. No movement was observed with potassium chloride or cadmium sulphate under any conditions. Movement was observed with ferrous sulphate, ferric chloride, and nickel sulphate under conditions of non-uniform concentration.

These experiments demonstrate conclusively that the general movement of the liquid, disclosed by refractive index striations, depends essentially on the presence of ferrous or other ions of high magnetic susceptibility. We wished to be sure that the movement of the bubbles formed at the unprotected ion pole-pieces was also due to the movement of the liquid, caused by the presence of the ferrous ions, which are provided by the solution of the pole-pieces in the acid. Accordingly the pole-pieces were heavily plated with cadmium and were then immersed in dilute hydrochloric acid. Bubbles of gas were liberated as before, but their motion in the liquid was entirely unaffected by the magnetic field: it was impossible to tell from their motion whether the magnetising current was switched on or not.

"In addition to the motion of the bubbles in the magnetic field, Ehrenhaft is also reported to have claimed that oxygen is evolved at the north pole and hydrogen at the south pole. Accordingly we immersed the bare iron pole-pieces in dilute hydrochloric acid and collected the gas from each pole separately. To facilitate this, a thin strip of mica was placed between the poles. The oxygen content of the gas was determined by heating a platinum filament to redness in it. A slight contraction in volume took place, corresponding to 0.54 and 0.49 per cent of oxygen in the gas from the north and south poles respectively. As the probable error in analysis was $\pm$0.03 per cent of oxygen, no difference in the gases collected at the north and south poles was detected. The presence of a small amount of oxygen was expected for two reasons. First, the pole-pieces became warm during the course of the experiment (due to the current in the magnetising coils), and air dissolved in the acid would then be evolved. Secondly, there will be a non-equilibruim interchange of gas at the bubble-solution interface. When a bubble of hydrogen is formed in a solution saturated with air but containing no dissolved hydrogen, air (and water-vapour) must pass through this interface inwards in an attempt to establish partial pressures equal to those existent over the solution, and hydrogen must pass outwards into solution in the liquid phase. Theoretically, if the bubble rose so slowly that equilibrium was attained by the time it reached the surface, it would then consist entirely of air (and water-vapour) and would have a hydrogen content of zero! Practically, of course, the interchange is not sufficiently rapid to induce more than a small oxygen-nitrogen content in the bubble. It

(*concluded on page* 433.)

Birds couldn't fly . . . . . without METALASTIK

Nature has always known how to grow muscles out of the main bone structure. It is true that she does not use metal and rubber, but the advantages gained are exactly the same as from the Metalastik rubber-to-metal weld.

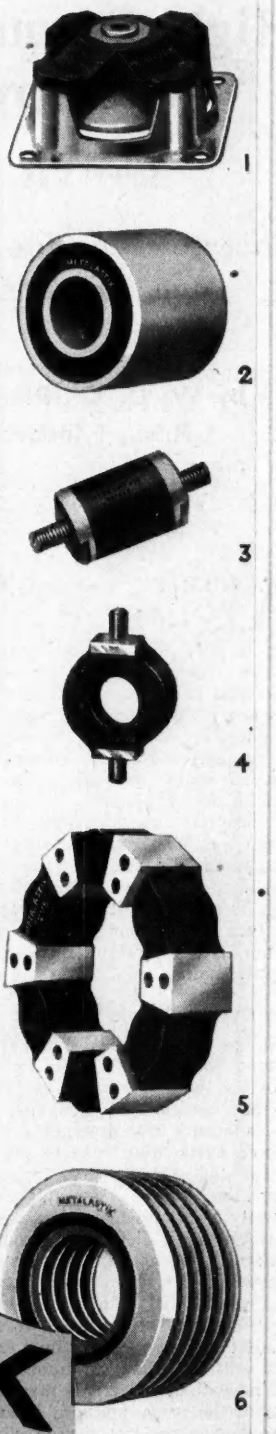
Who could imagine a bird built up like a Meccano outfit, or a ballet dancer with buffer springs and the backlash from a hundred Hooke's joints ?

Hitherto, nature alone has held the secret of 'natural' flexibility, but to-day mechanical engineering is broadening in its scope, by reason of this new flexible construction brought about by the scientific use of rubber, natural or synthetic, in conjunction with any of the metals commonly in use.

Instead of rubber looped on as a tension member, or sandwiched in as a buffer, rubber to-day can be integral—for all practical purposes—with the metal parts with which it is designed, yet with pre-determined resilience. The scope in design is limitless, because rubber has three quite different moduli ; in compression, in tension and in shear ; and we at Metalastik can control the movements of a part so that the elastic characteristics of constraint are different, not only against bodily translation, but also against rotation in every plane.

The illustrations at the side show :—

1. The cross-type mounting for instruments, embodying an overload device, made in an extensive range.
2. Metalastik rubber-to-metal welded bush. Rubber gives elasticity in compression, tension, linear or torsional shear, separately or in combination. Increased load-capacity, rubber does not leave metal under heavy load. In wide range of sizes.
3. The simplest type of instrument mounting, virtually a stud with a rubber 'middle.'
4. Another simple type of Low Frequency mounting for instruments, etc.
5. The Z.V.S. flexible coupling element ; alternate blocks bolted to driving and driven flanges respectively. This permits angular and axial disalignment ; cushioned drive with emergency positive engagement. For powers from 1/15 H.P. to many thousand H.P.
6. Where high-duty designs are needed with low weight, Metalastik gives outstanding results. This small unit is an elastic mounting for an aero engine, all metal parts are of Duralumin, to which the Metalastik rubber-to-metal weld is as efficient as to steel, etc.



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High Frequency Therapy

Part VII

Therapy Machine Design and Operation

by W. D. OLIPHANT, B.Sc., F.Inst.P.*

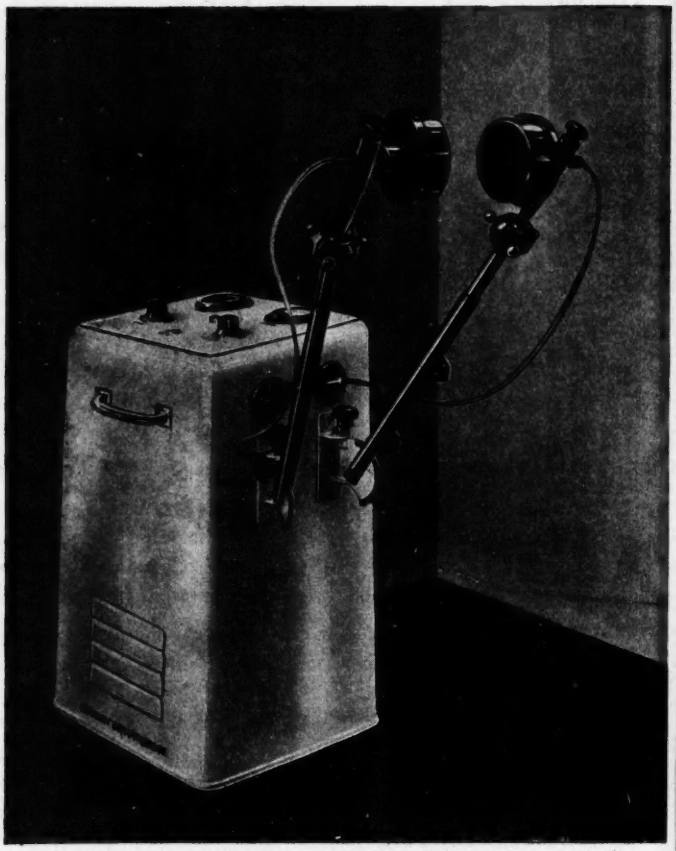

Fig. 7. "Intertherm" U.S.W. Therapy Equipment. Wavelength 6 m. Power 450 w. The illustration shows electrode arms fitted.
(By courtesy of Messrs. Stanley Cox, Ltd.)

A THERAPY machine is essentially a device for converting electrical energy derived from the supply mains at commercial power frequency and potential to electrical energy at the desired radio frequency and potential most suited to effective therapeutic treatment; it is, in fact, a medium power, mains driven radio frequency generator which can be operated in any room or hospital ward where ordinary power points have been installed. The essential features of any therapy machine are shown schematically in Fig. 1, and we will discuss each part in turn commencing at the patient terminals and working through to the supply mains.

The Output Circuit

It has already been stated that the output (or patient) circuit must be provided with a means for tuning it to the frequency of the generator so as to ensure the maximum possible power output and also to provide a means, when necessary, for controlling the output current. This is usually accomplished by means of a variable air-dielectric condenser which has been specially designed to withstand a high operating potential and which will also provide a sufficient capacitance variation to accommodate a range of working frequencies and electrode arrangements.

The patient current is measured by one of the many methods already referred to in the last section, although in certain of the earlier machines the only indicator, usually of resonance, was a simple neon discharge tube wherein the intensity of discharge glow provided the necessary evidence. With this method, which depends on indicated field strength, the dosage had to be estimated from a prior knowledge of the machine output for a given setting of the controls on the generator.

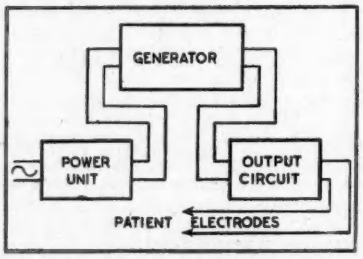

Fig. 1. Essential features of therapy apparatus.

Most modern machines are designed to cover a number of frequency bands or ranges, and it is thus necessary to include suitable switchgear in order that the circuit constants may be altered.

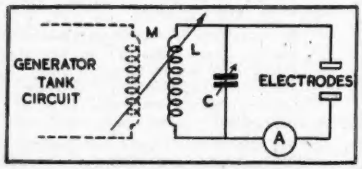

Fig. 2. Typical output circuit using indirect inductive coupling.

There are many possible ways for coupling the output or secondary circuit to the generator primary or tank circuit such as conductive or reactive coupling; but the over-riding consideration is that of safety on the patient's behalf. This compels us to use reactive coupling which may be either inductive or capacitive; in practice *indirect* inductive coupling is most favoured in view of its inher-

* University of St. Andrews.

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ent simplicity and ease of adjustment. A typical output circuit employing this form of coupling is shown in Fig. 2.

In this arrangement, provision can be made for varying the degree of coupling by suitable design of the coil assembly unit and so we have an additional means for controlling the output. The circuit can be made doubly safe for the patient as far as risk of serious shock is concerned (as the result of accidental contact, say, of the coil with the generator high tension), by the simple expedient of earthing either one end of the coil or its mid-point. The actual patient electrodes are connected to the output terminals by means of insulated flexible leads which are provided for plug and socket union.

The complete theory of operation of such a coupled circuit when taken in conjunction with the constants of the generator tank circuit will be found in any text-book which treats of circuit theory. There is one interesting theoretical point, however, which is worth noting and which concerns the case when the mutual inductance (M) is variable and when the two circuits are in syntony. As M is varied from its minimum to maximum values, the current in the output circuit will increase rapidly to a maximum, and then decrease less rapidly. The current maximum will occur for a value of M given by

$$M = \frac{R}{\omega}$$

where ω = the angular frequency = $2\pi \times$ frequency in c./s.

R = the geometric mean of the effective resistances of the tank and output circuits.

A typical *indirect* capacitive coupling arrangement which would prove equally efficacious is shown in Fig. 3, the fixed condenser network forming the capacitive coupling link which replaces the mutual inductance of Fig. 2.

Direct coupling of either reactive variety would not provide the necessary safety factor in that there would be a direct conductive connexion from the tank circuit to the patient electrodes.

In mechanical construction, the output circuit must be a rigid one and the coil is usually wound with either heavy gauge copper wire or tubing which has been suitably plated. The choice of suitable insulating material is of considerable importance and is made with regard to the following points:—

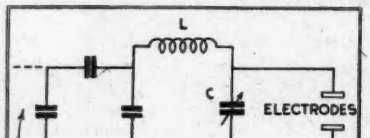

Fig. 3. Output circuit using indirect capacitive coupling.

(a) *Mechanical strength.* — Apart from the effective constructional loading, the effect of temperature rise on the mechanical properties of the material must be taken into account. This is of some considerable importance as most machines are designed for compactness and transportability and quite high ambient temperatures are reached especially in close proximity to the valve;

(b) *Loss angle.*—This should be as low as possible especially with ultra-high frequency working. A high specific resistivity is called for;

(c) *Dielectric constant.*—Apart from the consideration of actual capacitive circuit elements wherein a high dielectric constant is consistent with compactness, stray capacitances should be kept as low as possible. Supports should, therefore, be so designed so as to involve an absolute minimum of capacitance between the supported component and the machine chassis, consistent, of course, with adequate mechanical strength;

(d) *Dielectric strength.*—A knowledge of the maximum operating potentials is essential and a material so chosen as to withstand the stress. Some knowledge of temperature effect is indicated and when the patient's safety is directly involved, a suitable factor of safety must be decided upon.

The above points naturally apply throughout the design of the entire machine.

As far as pure research is concerned, the output circuit may, with advantage, be a tertiary circuit; the secondary circuit in such an arrangement being used as a critical adjustment of coupling and load matching and also to act as a filter especially in cases where source harmonics and severe output damping are present. At ultra-high frequencies the conventional LC circuit must of necessity be replaced by a portion of transmission line or Lecher wire system wherein the patient or test electrodes would be set at a potential antinode. At still higher frequencies the cavity resonator would be used. The cavity resonator would, in fact, form a very valuable research weapon as it would afford a ready means for direct output power measurement by calorimetric methods, the resonator itself forming part of the calorimeter proper. It must be realised, however that the use of a cavity resonator will involve quite a new theoretical analysis, as the biological material under test will now be placed in what might be termed a static wave field. It would, in fact, be a special case of the general spatial wave field therapy wherein actual free wave radiation from a source is brought to a focus by mirrors and lenses in just the same manner as optical and thermal waves. Little or no information has as yet been published on this aspect of radio frequency therapy which, at extremely short wavelengths, would appear to have distinct possibilities particularly in the case of superficial maladies where the absence of deep penetration is not a serious factor. The energy could doubtless be directed from the source to the patient radiator system by means of the now familiar wave guides.

In conclusion, it is necessary to provide a means for ascertaining the precise frequency of operation, and this generally takes the form of a simple tuned circuit incorporating a variable condenser which has had its dial calibrated directly in frequency or wavelength. A neon discharge tube is employed as resonance indicator, and provided the unit is capable of being effectively held at a distance consistent with a glow discharge taking place, a high degree of accuracy can be obtained. In practice, this wavemeter unit may either be incorporated in the general assembly of the machine or it may take the form of a separate element. In this latter case it may also be used as an indicator for exploring the potential distribution in the external patient circuit. At ultra-high frequencies the Lecher wire system would again be adopted.

The Generator

In normal practice a maximum power rating of about 500 watts is adequate, and in the majority of commercial machines up to the present the lowest operational wavelength is of the order of 3 metres (100 Mc/sec), while the highest is of the order of 300 metres, the latter being used mainly for pure diathermy purposes. As a rule machines are available only for operation within narrow limits about wavelengths of 300, 30, 6 and 3 metres, these having been found to be most advantageous in present clinical practice.

In the earlier machines, operating mainly about 300 metres wavelength, a spark generator was employed, but with the more recent use of the shorter wavelengths, valve generators are now taking their place, although it is still possible to obtain spark machines which will operate satisfactorily on the shorter wavelengths. Spark machines are very robust and their circuit requirements are simple, but they suffer from one serious defect and that is that they are rich in harmonics and tend to become very potential devices for setting up serious interference with telecommunication channels. As the spark machine is, however, still in widespread use, a brief account of its main features will be given here before passing on to the valve machines. The question of interference will be deferred till a later article, when therapy machines as a whole will be treated.

(a) Spark Generators

These machines are only capable of producing damped oscillations, that is

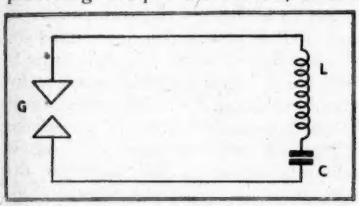

Fig. 4. Basic spark generator circuit.

to say oscillations whose amplitude decreases in a characteristic manner with time depending on the circuit decrement. In Fig. 4 is shown a basic spark generator circuit wherein L and C comprise the tuned or tank circuit and across which is connected a spark gap G.

We will assume that the condenser is capable of being charged up to a high potential at regular intervals, and that the gap width has been so adjusted that as soon as the condenser has received its maximum charge the potential gradient across the gap is such that a discharge takes place. When this occurs the gap now becomes conductive and enables the condenser to discharge. When the potential energy in the condenser has been fully expended it appears as kinetic energy in the inductance (magnetic energy) and as a result of electrical inertia (inductance) the current will continue to flow in the same direction at the expense of the kinetic energy. By so doing the condenser will become charged in the opposite sense. The energy in the system, which is again potential, will now initiate a current in the reverse direction and the same sequence of events will ensue until the gap ceases to conduct. During the conduction period of the gap it is evident that the current is of an oscillatory nature, the precise frequency being dependent on the values of L and C, and further that there must be a dissipation of energy due to the resistance of the circuit, hence the ever-decreasing amplitude of oscillation. A very simple mechanical analogy is to be found in the case of a piece of highly elastic material clamped at its upper end and supporting a weight at its lower end. When this system is displaced from its zero or equilibrium position, the weight will oscillate to and fro. The elastance of the spring corresponds to electrical capacitance; the inertia of the weight to inductance, and the vibratory motion to the current. The damping, corresponding to electrical resistance is provided by the air resistance and by the internal frictional forces within the material of the spring.

The duration of the oscillatory discharge is dependent on the energy in the circuit being capable of maintaining the ionisation of the gap, and the " packet " of oscillations is known as a wave train. These trains will recur at a frequency governed by that of the supply of energy from the mains. The necessary theoretical condition for an oscillatory discharge is that the effective resistance of the circuit be less than

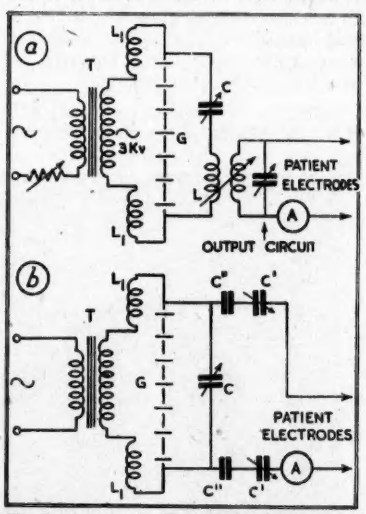

Fig. 5 (a) and (b). Typical circuits for spark generators.

$2\sqrt{\frac{L}{C}}$, otherwise the discharge will be of a non-oscillatory or unidirectional nature.

Typical circuit diagrams of spark machines are shown in Figs. 5 (a) and (b).

In both cases the supply voltage is stepped up to the order of 3 kv. by means of the transformer T, and provision for variation over a given range can be achieved either by a primary tapping switch or by a series resistor or inductor, either of which can be varied. An induction regulator could also be employed. The transformer secondary is connected through two h.f. chokes L_1 across a multiple spark gap G, which is capable of being adjusted throughout by means of a set of external controls usually placed at the back of the machine cabinet. Across the gap in Fig. 5 (a) is connected a simple series LC tank circuit to which in turn is inductively coupled the output circuit. The tank circuit is tuned by means of the variable condenser C. In the case shown in Fig. 5 (b) the inherent inductance in the circuit is used in conjunction with the variable condenser C to define the operational frequency, while the output circuit is indirectly coupled capacitively to it. The output circuit condensers C' can be operated in conjunction with C off a common spindle, while the fixed condensers C'' afford the necessary factor of safety for the patient.

The use of a multiple spark gap is essential in order that the gap efficiency may be maintained at the shorter wavelengths and this is further made possible by individual adjustment of each gap in the series. It is a characteristic with any given spark machine that the output drops considerably with increase in frequency.

The entire spark generator unit can be housed in a compact metal cabinet, which in the normal course of events should be earthed to provide operational safety. Considerable attention must be given to ventilation, and the spark gap assembly should be so constructed and mounted as to permit of adequate cooling; in addition to being fitted with liberal cooling fins, the gaps should be placed in the draught from a small fan installed within the cabinet.

(b) Valve Generators

The theory and practice of the many possible valve oscillator networks would require a whole series of articles to itself, but we are fortunate in the commercial aspect of machine design in that reliability and economic simplicity are the deciding factors, and so it comes about that the well-known Hartley oscillator circuit is the most popular. A typical circuit diagram of such a single-valve generator unit is shown in Fig. 6.

The tank circuit is made up of L_1 and C_1 and this is connected directly to the anode of the valve on one side and to the grid on the other by means of the grid coupling condenser C_2. In many designs where the wavelength is fixed, the condenser C_1 is dispensed

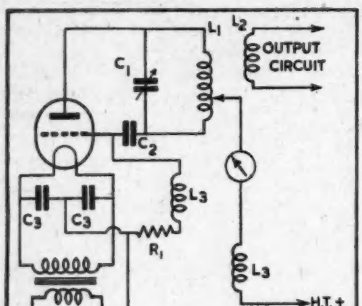

Fig. 6. Single valve generator unit.

with and the inter-electrode valve capacitance takes its place—this is particularly so at the shorter wavelengths. The grid is connected to earth through an h.f. choke L_3 and the normal grid resistance R_1. The cathode is energised in the usual manner by means of a separate heater transformer and the electric centre point is obtained by means of the by-pass condensers C_3, and is earthed. The H.T. supply is connected as shown and the chokes L_3 are incorporated to prevent h.f. energy from flowing back into the power unit. The tapping point for the H.T. connexion on L_1 is found by experiment to give optimum output under average loading. In certain designs, which operate on a fixed wavelength, the chokes L_3 are replaced by simple LC absorption circuits which are tuned to the fundamental operating frequency. Such absorption circuits may with advantage be included also in the two cathode heater leads.

In order to generate say 300 watts output power at about 100 Mc/sec. it is necessary to employ a valve which will have an anode dissipation of the order of 1 to 1.5 kw., and as the generators are designed for compactness, elaborate cooling precautions have to be taken involving the use of a fan mounted directly below the valve.

Some control of the power generated by the valve is an advantage, and in many commercial designs this is achieved simply by altering the cathode heater current. This, however, is not regarded as good practice from considerations of valve life, especially with certain types of filament and so some form of H.T. adjustment is to be preferred. The machine as a whole is controlled by a single main switch and it is common practice to include a thermal delay switch in the H.T. feed so that the valve is not energised until the cathode has assumed its normal operating temperature.

Ranging is made possible by mounting the tank coils on a rotor, each coil being inserted in circuit through the medium of high-class switch contacts. Such rotor assemblies include also padding condensers which are permanently connected across their appropriate coil so that the correct wavelength may be excited. All h.f. circuit connexions should be made with heavy gauge copper strip or tubing which has been silver plated. Wherever possible the circuit components should be so mounted as to avoid " heat pockets " in the general assembly, and they should be so orientated that dust will not impair their efficiency. This point is worth noting as the generator cabinet, for purposes of ventilation, must be liberally equipped with louvres. For operational safety and for screening purposes, the cabinet is made of metal and some idea of the general appearance of a typical valve machine is given in Fig. 7.

This machine operates on a fixed wavelength of 6 metres and has an output power of 450 watts. There are two controls on this instrument: one for tuning and the other for power adjustment. As is seen, the cabinet is also equipped with a pair of insulated arms so that the condenser electrodes can be held in any position. The unit is a transportable one, being mounted on wheels for ease of propulsion.

In Fig. 8 we have a typical example of a portable machine, that is to say one which can be carried as distinct from having to be wheeled about. Again the operating wavelength is 6 metres, but the output power is now 250 watts. In the illustration a single electrode is in use for sinus treatment, thus obviating unintentional radiation of the pituitary body. The second or indifferent electrode, as can be seen, is of the flexible-pad variety and is not in actual contact with the patient.

With increase in operational frequency the physical dimensions of the tank circuit must come down until a limit, set by valve inter-electrode capacitances, is reached. Still higher frequencies will thus involve the use of the magnetron and possibly the klystron. For certain more refined purposes it may be necessary to generate at low power and incorporate a power amplifier in the output.

The Power Unit

In the spark machine this consists simply of a step-up transformer as was seen in Fig. 5. In the valve machines conventional designs of H.T. supply units are incorporated. In many machines " raw A.C." is applied direct to the anode of the valve and so the output efficiency is lowered and is heavily modulated. In the better design, however, a suitable power rectifier and smoothing circuit is employed, the rectifier being either of the thermionic or gaseous discharge varieties.

(To be continued.)

Fig. 8. Portable U.S.W. Therapy Equipment 6 m. 250 w., with single electrode in place for sinus treatment.

(By courtesy of Messrs. Stanley Cox, Ltd).

Electronic Oxide Finishes for Aluminium

THE oxide finishes formed on aluminium by anodic treatment in various electrolytes comprise one of the most important classes of finishes for aluminium. The hard corundum-like anodic coatings, which can be formed only on aluminium, are most durable and give protection and permanence to the surface. They are attractive in appearance, have high resistance to corrosion, high dielectric strength, high reflectivity and good adsorption for dyes and mineral pigments. The properties of the coatings vary, depending on the composition of the alloy, the composition of the electrolyte and the temperature and voltage of operation, as well as the time of treatment.

The patented Alumilite process (Aluminium Company of America, Pittsburgh) comprises anodic treatment of aluminium in a suitable electrolyte so as to secure a dense, adherent coating of aluminium oxide. The process differs from electroplating in that the articles to be treated are attached electrically as anode rather than cathode in the electrolyte. In electroplating, a metal is deposited on the article being coated, while in anodic treatment, in effect, oxygen is deposited instead of metal and combines with the aluminium to form aluminium oxide, integral with the surface of the metal.

Some Alumilite coatings are very adsorptive. By immersing the articles in a suitable dye bath, the dye penetrates the coating, giving deep colours which have an attractive underlying metallic sheen. It is, however, recognised that these dyed coatings will eventually fade on continued exposure to the weather, and therefore these coloured finishes are best used for interior service. For more severe service, mineral pigment may be adsorbed in the coating. These colours are not usually as brilliant, nor do they produce the translucent effect of the dye colours, but they possess a greater light fastness.

Hard finishes are not adaptable for certain forming operations, because of cracks which occur at relatively sharp bends. By the proper selection of the electrolyte and the coating conditions, however, it is possible to produce a finish that may be fabricated without visible cracks, but resistance to corrosion is sacrificed by this procedure.

Laminated Wood as an Insulator

By A. E. L. JERVIS, A.I.E.E.

Corrections

In the February issue of this Journal several references were made to the excellent paper by Mr. J. P. Taylor, published in the April, 1943, Transactions of the A.S.M.E. Owing to a typographical error the wrong watts were given in the calculations, and in case this is misleading to the reader, these calculations are repeated at the end of this note.

The Impulse Flashover Tests (Fig. 11) were carried out in the High Voltage Laboratory of Queen Mary College, University of London, *under oil*. It is the Impulse Flashover *in air* Fig. 9, which was taken from the Sporn & Lusignan paper.

Finally, in Table I, the various strengths in lbs. per sq. in. should be 10^3 lbs./sq. in.

We apologise to the author for allowing these errors to remain uncorrected in the proofs.

High Frequency Heating

Assuming that the resin is cured in 30 mins. and that the power required in watts per cubic inch, is 2 watts (*see* Fig. 10).

Power required per cubic foot.

$$= 2 \times 1{,}728 = 3{,}456 = i_r^2 R_p$$

Current i_r

$$= \sqrt{\frac{3{,}456}{2.36 \times 10^5}}$$

$$= \sqrt{0146} = 0.122 \text{ amp.}$$

Voltage E

$$= i_r R_p = 0.12 \times 2.36 \times 10^5$$

$$= 28{,}320 \text{ volts.}$$

Apparently voltages in excess of 15 kV are not advisable for various reasons, such as the appearance of corona trouble, etc. If the calculations are repeated for a frequency of 10 Mc./s., the required voltage is 9 kV.

Note : In the original article the author was designated Associate Member I.E.E., instead of Associate I.E.E. Further apologies to both parties.—Ed.

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CORRESPONDENCE

Simplified Symbols

DEAR SIR,—With reference to the points raised by your correspondents in the January issue, I would again like to stress that my purpose was to ease the work of the professional draughtsman in addition to suggesting a simplified international code.

I cannot agree with Mr. Lane-Smith's comment that the specimen diagram looks messy, but when one has been used to seeing things in a certain way for many years no doubt it looks odd to see them from a fresh angle.

I agree that perhaps the use of thicker lines for the circuit may be an advantage and would involve the draughtsman in less trouble than in changing his drawing instrument from pen to compass.

Regarding the tendency to "Americanise" diagrams, I am in agreement with your correspondent—the specimen circuit was adapted from an existing British circuit.

I agree with Mr. Stevens that the engineer may find it more convenient to sketch his ideas in the old style, using any form of symbol he prefers, so long as the final blue-print is standardised by the draughtsman.

With regard to his comment that the "dot" grid symbol is usually drawn with only two or three dots, I would refer him to some of the published diagrams in this journal.

I do not think that the removal of the envelope from the valve symbol would make the diagram look more simple.

I heartily agree with Mr. Stevens' suggestion for denoting the gas filling in a valve by the chemical symbol of the gas instead of the conventional shading, and hope that this will be adopted as standard practice.

In conclusion, I would like to thank them for their helpful remarks, and would be pleased to receive comments from other readers.

Yours faithfully,

D. B. SHANNON.

Editor's Note.—It is regretted that Mr. Shannon's reply has had to be curtailed slightly for lack of space. We would point out that the drawing of diagrams for blockmaking involves less trouble than for blue-printing, and it is possible to use "mass-produced" symbols.

One suggestion that we would make is that the use of a stylo pen for lining results in perfectly uniform thickness of line, and saves frequent refilling of the pen.

A Legitimate Grievance

DEAR SIR,—Writers of text books, particularly those concerned with the popular sciences such as Radio Engineering, frequently receive requests for technical information from readers and students. An author is generally very pleased to help in solving technical difficulties, but it seems unfair that he should be expected not only to provide free advice, but also to pay for conveying the reply to the enquirer. In my case, only one out of a fair sized mail bag has so far remembered that an author (of technical books at least) is not a man of unlimited means. His reply to my thanks for this elementary courtesy is perhaps worth quoting: "Why not include in the preface a reminder that readers who have bought the book have not bought the author"?

This omission of the stamped addressed envelope, is probably due to lack of appreciation that the questioner is not the only one writing, and I should be very grateful if you would give this joint publicity in the correspondence columns of your Journal.

Yours truly,

AN AUTHOR.

Slow Motion Oscillators

Sir,—There are a number of points in the article by Mr. C. H. Bulman on "A Slow Motion Oscillator for Class Demonstration" (published in the December, 1943, issue) with which I cannot agree.

Mr. Bulman states the frequency of oscillation is reduced to about half a cycle per second and later that an inductance in the region of 100 henries is required. An inductance of this value with a capacitance of 6 mfd (as shown in the diagram) gives a resonant frequency of 6.5 c.p.s.

The inductance of the two windings of a normal intervalve transformer is much greater than 100 henries. I have recently measured a few and found them to vary from about 1,500 to 6,000 henries. This presumably accounts for the low frequency obtained by the author.

The oscillator obviously works as a dynatron oscillator with the filament connected to HT. The author does not state what valve he uses but since it is directly heated it must be a battery type. The maximum screen voltage is usually about 100 volts, and Mr. Bulman's figure of 202 volts seems excessive. I have tried the circuit and had oscillations at about 2 c.p.s. but the adjustment of the bias and the anode voltage were very critical due to the low Q of the tuned circuit.

Since the dynatron does not work on the feedback principle as in the case of most oscillators it is not a desirable circuit on which to explain the action of an oscillator. I have found that the moving coil meter I_a measuring anode current shows an A.C. current (at this low frequency this appears to be the only point on the dynatron characteristic where oscillation occurs and I suspect that the dynatron is not working in the normal way). This is apt to be misleading to students since all normal valves cannot have a negative (reversed) anode current.

The use of an A.C. meter for I_c surely defeats the object of reducing the frequency, since an A.C. meter will either show kicks in the same direction or a steady reading depending on the damping of the meter. A centre zero moving-coil meter would be superior.

Yours faithfully,

G. N. PATCHETT.

Sir,—I have to thank Mr. Patchett for his kind interest in the suggested oscillator and for his comments upon its operation. It would appear that the figure for the inductance was underestimated in the article, but four windings of the two L.F. transformers will certainly produce a frequency of the order stated.

As the article was offered in the form of a short note I did not consider it necessary to mention the dynatron principle as it was obvious that the valve was intended to function in this way in such a circuit. With regard to the type of valve, the Osram SG215 or R.A.F. VR18 have been successful and both types survive the high screen voltage necessary. This may be due to the fact that the apparatus is only in use for a few moments at a time.

The difficulty with the appearance of the anode current is, I think, due to the fact that Mr. Patchett's oscillator was not working slowly enough to follow the inertia of the meter needle. The anode current should certainly not look like A.C. The suggestion about the use of a centre-zero instrument for the circulating current is, of course, an excellent one and I ought to have mentioned it.

The fact that the dynatron circuit has been used has not proved confusing to the trainees, because the apparatus is used, as my article explained, to demonstrate the fact that the circulating current in an oscillatory circuit is alternating in character, and nothing more. For explaining "squegging," "self-bias" and other effects, a different type of circuit is used. I hope

CORRESPONDENCE—*Contd.*

Mr. Patchett will find the suggestion worthy of further investigation and I look forward to seeing in print shortly the oscillator he has been using.—Yours faithfully,

C. H. BULMAN.

The Muirhead-Wigan Oscillator

Dear Sir,—We note that in his paper on the synchronisation of oscillators, in the April, 1943, issue of ELECTRONIC ENGINEERING, Mr. Tucker refers to the circuit of the Muirhead-Wigan oscillator as originating in America.

Although this circuit may have made a separate appearance in the United States, it was developed quite independently in this country by the late Mr. P. W. Willans.

A patent application was made in April of that year (No. 497,148) and oscillators using this circuit were in production in 1938.

The Muirhead-Wigan oscillator is one of several types which we have made using this circuit and which is distinguished from the others mainly by use of the decade tuning principle.

—Yours, etc.,

W. C. LISTER,
Chief Development Engineer.
Muirhead & Co., Ltd.

A New Discovery in Physics??

(*Concluded from p.* 424.)

would seem to be rather difficult to prevent the presence of a little oxygen (due to these causes) in the collected gas, and perhaps Ehrenhaft's reported observation may be accounted for in this way.

"A third reported observation—that the pole strength of a permanent magnet decreases when immersed in dilute acid—we have not attempted to confirm. If sufficient of the permanent magnet were dissolved away, there would, of course, be a measurable decrease in its pole strength.

"Our interpretation of the experiments we have made here may perhaps explain the effects attributed in the Press to Ehrenhaft. These may turn out to be no more valid than his previous claims of the existence of charges smaller than the electron (see *Phys. Z.*, 21, 675, 683; 1920). However, we must reserve final judgment until a fuller account of his experiments is available."

NOTES FROM THE INDUSTRY

Metro-Vick Research in 1943

Research activities of the Metropolitan-Vickers company have, as in past years, included much work associated with the investigation, study and testing of materials and the control of processes of manufacture, in addition to considerable work of an advisory and highly technical nature concerning factory and third-party requirements.

A continuously evacuated cathode ray oscillograph has been completed during the period and delivered to customer, the equipment including a valve delay circuit enabling long-time transients to be examined in sections. This instrument embodies many improvements in detail as evolved over a number of years, and is capable of recording very high frequencies.

Certain physical properties of high-pressure spark discharges have been studied and some new methods of studying such discharges have been developed giving preliminary results of considerable promise. The onset of glow discharges in various gases at low pressures has also been investigated. Magnetic investigations have included problems concerning the detection of flaws in materials and the development of a field strength indicator for fields of 100-2,000 H. Equipment for this type of magnetic testing has been in good demand and no major changes have been found necessary in the design of the various models available, though some small improvements have been incorporated to simplify the operation of some units and to enable special types of components to be tested.

In the acoustics field an investigation into the errors of the Rayleigh Disk method of microphone calibration has been completed and a study has been made of sound attenuation in air ducts.

Berry's (Short Wave), Ltd.

Messrs Berry's (Short Wave) Ltd., announce that they have opened a London branch at 25 High Holborn, near Chancery Lane station. The management is in the hands of Mr. E. W. Dean, who will be known to many readers from his recent association with Messrs. Webbs Radio.

Messrs. Trix, Ltd.

have changed their address to 1-5 Maple Place, Tottenham Court Road, W.1. Tel.: MUSeum 5817.

Transradio, Ltd.

Co-Ax Cable Data

An illustrated folder describes the electrical properties of Co-Ax H.F. Cables, manufactured by Transradio Ltd., of 16, The Highway, Beaconsfield, Bucks. The outstanding features of these cables are extremely low capacity (8.8—5.3 $\mu\mu$F. per foot) and low attenuation constant (from 1.9 to 0.45 db. per ft. at 100 Mc/s.). Cables are manufactured in three types: Low Attenuation, Low Capacity, and Intermediate, and eleven ranges in all.

Messrs. Hammans Industries

The share capital of Messrs. Hammans Industries Ltd., having been acquired by De la Rue Plastics Ltd., a new company has been formed under the title of De la Rue Insulation Ltd., with showrooms at Imperial House, Regent Street, W.1.

The new company will manufacture and distribute the products hitherto made by the two companies, notably "Delaron" laminated plastics, Delarex insulating board, "Hamolac" sleeving, and "Hamofil" insulated wire.

Bristol Engineering Manufacturers Association

This Association would be pleased to receive copies of any publications issued by firms, dealing with processes, heat treatments, raw materials, and new products. Details of all the publications received are circulated to the 140 engineering firms who are members, and are filed in the library for reference.

T.E.M.A.

The Telecommunications Engineering and Manufacturing Association was referred to last month under the initials T.E.M.E. instead of T.E.M.A. Readers of Freud will no doubt appreciate the subconscious influence of the war and R.E.M.E.

Obituaries

We very much regret to have to record the deaths of two well-known figures in the radio industry:

MR. J. M. G. REES, Director of Oliver Pell Control Ltd., and of Varley Dry Accumulators, was largely responsible for the development of Varley Radio products, and was a popular member of the Radio Industries Club. He was universally liked for his pleasant personality and readiness to help all those with whom he came in contact.

COL. G. D. OZANNE, M.C., M.I.E.E., a Director of Wright & Weaire Ltd., was the first Chairman of the Radio Component Manufacturers Federation and was on the Council of the R.M.A. from 1932 to 1938.

BOOK REVIEWS

Radio Technology

B. F. Weller, A.M.I.E.E. 358 pp. (Chapman and Hall, 21s. net.).

The author states that he has aimed at providing a book intermediate between an elementary manual and a standard textbook, but that the treatment is sufficiently advanced to serve as adequate preparation for the Radio Communications paper of the Institution of Electrical Engineers and of the City and Guilds (Finals). To fulfil such a claim the book should include sections on wave filters, telephone terminal equipment, direction finding, and field strength measuring equipment. The value of the index would be greatly enhanced if the author would pay particular attention to indexing subjects in the examination syllabuses.

There are ten chapters; the first discusses general principles and the second the theory of damped oscillations and crystal detection. A shrewd guess would suggest that Chapter 2 is mainly included to help the prospective examination candidate. Chapters 3, 4 and 5 deal with the diode, multielectrode voltage amplifiers and power amplifiers respectively. Self oscillators, master oscillators and driven circuits form the subject of Chapter 6. The next chapter, on radio-telephonic transmission, actually deals with methods of amplitude modulating an R.F. carrier. The last three chapters are concerned with principles of reception, the supersonic heterodyne and aerial systems.

Turning to more detailed criticism, on page 13 it is stated that maximum selectivity for a parallel circuit occurs when the ratio of L to C is very small. This needs qualification, for in the absence of external damping Q is the sole criterion and the ratio $\frac{L}{C}$ has no effect except insofar as Q may change when L changes. On page 59 "the average value of a sine wave is $\frac{2I_m}{\pi}$" should read "the average value of two half sine waves resulting from full-wave detection is $\frac{2I_m}{\pi}$." The author suggests on page 64 that destruction of the coating of mercury rectifiers is solely due to excess electron emission and no reference is made to bombardment of the cathode by positive ions, which is the really serious problem. The discussion on triode detectors ought to include some reference to anode circuit feedback damping on the grid circuit, as it is far worse than grid current damping. The equivalent grid current damping resistance is far less than twice the grid leak when a shunt capacitance is used as shown.

The author does not seem clear on the reason for an optimum load of $2R_a$ for a Class A amplifier. It is not solely due to distortion but to the fact that the input voltage can be adjusted to suit the load requirements. If the input voltage is fixed, this is virtually so when the load resistance also carries the D.C. current, optimum load is R_a. Optimum load in a pentode or tetrode valve is quite easily calculable but is not a function of valve slope resistance. Pentode anode circuit efficiency (page 139) is not low but is very much better than that of a triode because of the lower minimum anode voltage. In Chapter 9, Fig. 91 shows a circuit for the triode, pentode frequency changer which will certainly not allow oscillation. Feedback across the cathode coil L_2 from the pentode section must be prevented by decoupling anode and screen circuits to cathode.

It is almost impossible to avoid misprints but these are few and for the most part obvious, such as "rectifier" for "rectangle" in Fig. 39. On page 7 reference to the coulomb as an enormous unit should read farad for coulomb.

The author quite rightly stresses that his aim is far wider than the preparation for examinations; it is in fact to provide a good technical background with a practical bias. He achieves this aim most successfully in the chapters on modulation, principles of reception and aerials.

K.R.S.

Radio Troubleshooter's Handbook

A. A. Ghirardi. 744 pp. 3rd. Ed. (Radio & Technical Publishing Co., 31s. 6d.)

This is a companion book to the author's "Modern Radio Servicing" and deals more particularly with troubles in specific receivers (American).

There are over 400 pages of "case histories" of receivers giving the symptoms and cures of various faults. After chapters on alignment and i.f. transformer servicing, the remainder of the book is crammed with useful tables and data, charts for ready reference in servicing, automobile wiring diagrams, battery and vibrator replacements, grid-bias resistor values and ratings, and anything that is likely to save the serviceman trouble and time.

At the end are charts for resistance and reactance calculation, time constants, design of transformers, R-C coupled stages, and finally a complete radio trade directory.

It must not be thought that a book of this type published in America is of limited application in this country. Apart from the number of American sets over here, the troubles are not peculiar to American proprietary sets and the British service engineer can learn a lot by analogy. Even if he never has occasion to refer to the case histories, the remainder of the book alone makes it worth the money.

Physics for Engineers

Sir Ambrose Fleming, F.R.S. 228 pp. 89 figs. (Geo. Newnes Ltd. 7s 6d.).

The first edition of this book appeared in 1941 when the author was at an age when he might be expected to be taking a well-earned rest from scientific writing, but on reading it one is assured that his powers of exposition are as strong as ever.

The book follows the standard introductory path of units, matter and electricity, electrostatics and electromagnetism, leading up to thermionic emission, radiation and the quantum theory, electron optics, and, finally, atomic transformation.

The last chapters are perhaps the most interesting part of the book and are an excellent introduction to the wave theory of matter. They are up-to-date in their inclusion of a brief mention of the cyclotron.

A minor criticism that might be made of the chapter on electrical measuring instruments is that the illustrations are not of modern types of instruments and that electrostatic and electromagnetic meters are not mentioned, but, as the author implies in his preface, the engineer will already have had a working acquaintance with these. In conclusion one can only quote the phrase on the jacket: "A masterly survey of present day knowledge in the realm of physics."

G.P.

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ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

Industrial Electronic Heating

(J. P. Jordan.)

This article covers the application of high frequency vacuum tube oscillators to the induction heating of metals and the dielectric heating of non-metallic materials. The theory of the vacuum tube oscillator is presented, together with that of eddy current and dielectric heating, with the aid of diagrams. The two major oscillator circuits in general use are described and compared.

—*G. E. Rev.* Dec., 1943, p. 675.*

Synthetic Resin Laminated Wood Insulation

(A. E. L. Jervis)

An outline is given of the development of laminated synthetic resin wood manufacturing technique from the plywood and laminated paper industries. Resins and resin content are noted in relation to the varying electrical characteristics produced. Uses of laminated wood in the electrical industry are listed and graphs, plotted from actual tests carried out by Moulded Components (Jablo) Ltd., are discussed. These cover surface breakdown in air of sheet material and round rod at 50 c.p.s., surface breakdown in oil of square rod, breakdown along laminæ of sheet at 50 c.p.s., dielectric (puncture) strength through laminæ at 50 c.p.s., impulse flashover of square rod in oil and moisture absorption tests.

—*Br. Plastics and Mod. Plastics*, Sept., 1943, p. 223.*

High Frequency Heating for Plastics

An account is given of the principles involved in the high-frequency heating of plastics. The plastic material acts as the dielectric of a condenser, the high-frequency electrical field causing uniform heat production. It is shown that since the capacity of the " condenser " and the power factor of the material are constant, the energy input can be controlled by altering either the voltage or the frequency. Thus, working with high frequencies, the required heating effect can be obtained employing low voltage. This ensures safety to personnel and minimises the danger of electrical breakdown of the material. Various applications are described.

—*Br. Plastics and Mod. Plastics.* Nov., 1943, p. 322.*

Properties of Laminated Phenolics

(L. E. Caldwell)

The more important physical properties of laminated phenolics are given and compared with corresponding properties of other materials. Both the quantity and type of the resins and of the fillers are stated to affect the physical properties to a marked extent. The paper-base grades are claimed to have the best electrical qualities. Methods of loading to obtain the greatest strengths are considered in determining the physical properties of these laminates. Stress-strain diagrams are set out and the mechanical and electrical properties tabulated.

—*Mod. Plastics*, Aug., 1943, p. 82*.

Modern Plastics for Insulation

(J. Veit.)

The author reviews the present and future possibilities of Polyvinyl Chloride, as applied to the electrical industry. He discusses the properties of P.V.C. insulation, with reference to typical applications. The advantages and disadvantages of the material are set out and it is claimed that P.V.C. is superior to rubber in many ways. Various finished P.V.C. products are described.

—*Br. Plastics and Mod. Plastics.* Nov. 1943, p. 353.*

MEASUREMENT

Temperature Compensation of Instruments with Negative Coefficient Resistors

(J. R. Pattee)

The effect of temperature variation on an electrical instrument in altering the accuracy of the readings is discussed. Methods of temperature compensation which merely reduce the effect of temperature by having a zero temperature coefficient resistance in series with the instrument are indicated and the advantages of using a series resistance with a high negative temperature coefficient which compensates for temperature changes are presented. Tests were carried out on silicon carbide resistance called Globar B made by The Carborundum Company and on others made by The Keystone Carbon Company. The development of a millivoltmeter for marine Diesel engine pyrometers is discussed and its application to the commercial Diesel engine pyrometer produced by the Bristol Company described.

—*Electronics*, Aug., 1943, p. 102.*

Direct-Reading Wattmeters for use at Radio Frequencies

(G. H. Brown, J. Epstein and D. W. Peterson)

The principle of paired thermocouples is used to make a practical operating instrument for the measurement of high power at radio frequencies Two instruments are described, viz. (1) one which is useful in the range of frequencies from 500 to 2,000 kc./s. and which contains circuits permitting operation at any frequency in this band with no tuning or other change and (2) an instrument for operation in the region of 50 Mc/s. which differs from (1) in the method of coupling the thermocouples to the transmission line. The theory of operation and methods of calibration are discussed. Test data taken on loads having a wide range of power factor are compared with power measurements made on water-cooled loads.

—*Proc. I.R.E.*, Aug., 1943, p. 403.*

Electronic Unit for Accurate Timing of Switching Operations

(F. O. Mason and K. Goldschmidt)

The unit described has been designed for use in experimental work wherever it is necessary to have a pre-determined and accurately timed sequence of operations. It consists of an initiating gas discharge relay which operates four mercury-filled grid control relays in any selected sequence of time differences of the order of 10^{-4} to 10^{-1} sec. (with provision for longer times) with a timing accuracy generally within $\pm$1 per cent. of the overall time. The circuit constants are such that a minute or two is required before a cycle can be repeated.

—*Jour. Sci. Inst.*, Vol. 20, 1943, p. 192.

CIRCUITS

Characteristics and Applications of Selenium-Rectifier Cells

(E. A. Harty.)

The construction and theory of typical selenium cells are explained and graphs presented illustrating characteristics and performance. The employment of the cells in rectifier circuits is discussed, attention being drawn to the fact that the rectifier resistance is not constant, but changes with time, current and temperature. Considerable data pertaining to cells manufactured by the General Electric Company (U.S.A.) are set out.

—*El. Engg.* Oct., 1943, p. 624.*

* Supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester.

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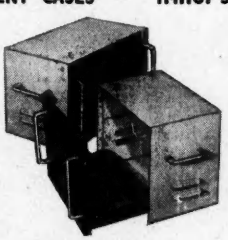

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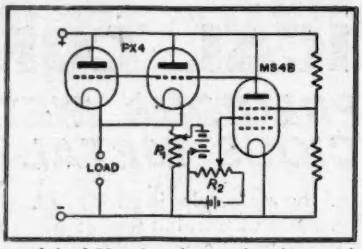
Electronic Stabiliser for Calibrating Voltage

IN a paper recently read before the Measurements Section of the Institution of Electrical Engineers, A. Glynne (Manchester College of Technology) describes a form of electronic stabilising circuit designed to provide a substitute for the high voltage battery used in standardising rooms.

The circuit is equivalent to a battery with an internal resistance of 2.5 ohms whose voltage can be smoothly adjusted from 80 to 600 volts. The voltage remains steady to within 1 part in 100,000 for a few minutes, and to 1 part in 10,000 indefinitely. The current available is 100 mA. or more.

The essential circuit of the stabiliser for voltage control consists of a valve V_1 connected in series with the load, together with a second valve V_2 whose function is to provide the grid of V_1 with the correct potential to maintain the output voltage of the stabiliser at a nearly constant value. The grid-to-cathode voltage of V_2 is equal to the output voltage minus the constant voltage of the bias battery, the difference being a few volts negative. An increase in the supply voltage produces some increase in output voltage which raises the grid potential of V_2, thus increasing its anode current and making the grid of V_1 more negative. The result is, therefore, that the greater part of the voltage increase is absorbed by V_1. An increase in the load current reduces the output voltage, thus causing the grid of V_2 to become more negative, and, consequently, the grid of V_1 to become more positive. This action gives the stabiliser a good regulation characteristic.



The circuit shown is an elaboration of this simple circuit. It may be noted that a tetrode, MS_4B, is substituted for the triode and that its screen voltage is supplied by a tapped resistor connected across the input voltage. An increase in the supply voltage therefore raises the screen voltage and consequently increases the effective resistance of the PX_4 valves. This is a true stabilising action and accounts for the improved result that is obtained.

Variation of the output voltage may be effected by changing the tapping point on the divider R_1 or by adjustment of the voltage of the bias battery. It has been found convenient to make use of both methods—the first for coarse and the second for fine regulation. The divider R_2 has a resistance of 1.5 megohms and is connected across a 3-volt battery. The battery switch changes the voltage in steps of 1.5 volts. In this way it is possible to control the output voltage smoothly to 1 part in 20,000 and there is no tendency to drift. Since there is no current flowing in the controlling circuit, variable contact resistances do not cause any fluctuation in the output voltage.

The current which can be supplied by the stabiliser is determined by the type of output valve used. The author uses two PX_4 valves, each rated to take 60 mA at 300 volts, in parallel.

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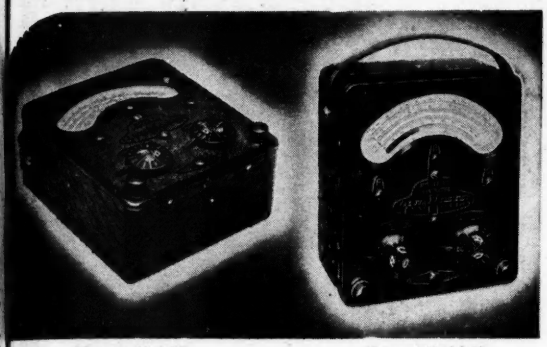

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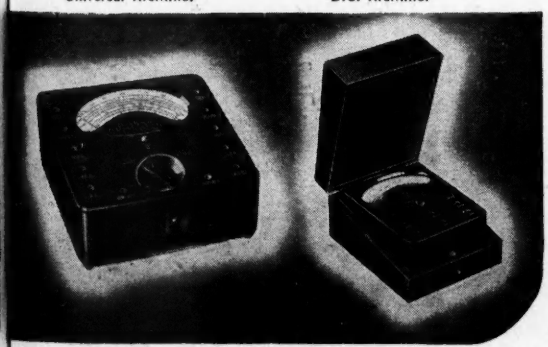

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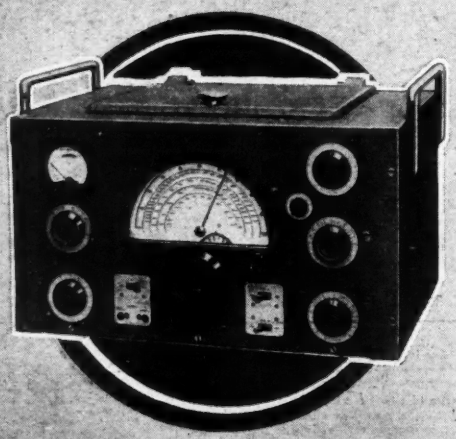

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